Section 6
Hazard Identification, Profiling, and Ranking

Contents of this Section

6.1 Interim Final Rule Requirement for Hazard Identification and Profiling

Requirement §201.6(c)(2)(i): *[The risk assessment shall include a] description of the type…location and extent of all natural hazards that can affect the jurisdiction. The plan shall include information on previous occurrences of hazard events and on the probability of future hazard events.*

This section addresses the specific requirements of the Interim Final Rule (IFR) with regard to hazards in the planning area.

6.2 Hazard Identification

In accordance with IFR requirements, and as part of its efforts to support and encourage hazard mitigation initiatives, the City of Galveston's Hazard Mitigation Plan Stakeholder Committee (HMPSC) prepared this general assessment of the hazards that have potential to impact the City. The following subsections provide an overview of past hazard events in the county and brief descriptions of the potential for future losses. Section 7 (Risk Assessment) includes much more detailed information about past and potential losses (risk) from a subset of the most significant hazards in the City.

The term *planning area* is used frequently in this section. This term refers to the geographic limits of the City of Galveston. The Risk Assessment section addresses the effects of hazards on the City of Galveston, its assets and residents.

6.2.1 Overview of the City of Galveston's History of Hazards

Numerous federal agencies maintain a variety of records regarding losses associated with natural hazards. Unfortunately, no single source is considered to offer a definitive accounting of all losses. The Federal Emergency Management Agency (FEMA) maintains records on federal expenditures associated with declared major disasters. The United States Army Corps of Engineers (USACE) and the Natural Resources Conservation Service (NRCS) collect data on losses during the course of some of their ongoing projects and studies. Additionally, the National Oceanic and Atmospheric Administration's (NOAA) National Climatic Data Center (NCDC) database collects and maintains data about natural hazards in summary format. The data includes occurrences, dates, injuries, deaths, and costs. It should be noted that many of these databases and other data collection services, including the NCDC, have inherent data limitations when searching for information at a scale as small as a single municipality. The best available data and records were used throughout this section.

According to the NCDC database, at least 88 weather-related hazard events have occurred in the City of Galveston between 1950 and 2010, including the following types of hazard events:

- Thunderstorms
- High Winds
- Hail
- Flooding
- Tropical Systems
- Waterspouts / Funnel Clouds / Tornadoes
- Coastal Erosion
- Lightning

In addition to the hazard events captured by the NCDC, the City has experienced several other hazard events. For example, at the height of Hurricane Rita, several fires broke out in Galveston. Due to the extreme winds buffering the island as Rita passed by, the City's Fire Department was unable to respond to protect the at-risk properties, leaving the fires to burn uncontrolled.

In the absence of definitive data on some of the hazards that may occur in the City of Galveston, illustrative examples are useful. Table 6.2-1 provides information on the Presidential Disaster Declarations that the City has received in the previous decade.

The City of Galveston has been included in 6 Presidential Disaster Declarations since 2001. Five declarations were related to tropical systems; the other was related to extreme wildfire conditions.

Table 6.2.1-1
Recent Major Disasters in Galveston, TX
(Sources: FEMA, City of Galveston)

Recent Major Disaster Declarations, 2001-2010	
Date and Disaster (DR, if applicable)	**Nature of Event**
September 2008 DR-1791-TX	Hurricane Ike
January 2006 DR-1624-TX	Extreme Wildfire Threat
September 2006 DR-1606-TX	Hurricane Rita
July 2003 DR-1479-TX	Hurricane Claudette
September 2002 DR-1434-TX	Tropical Storm Fay
June and July 2001 DR-1379-TX	Severe Storms and Flooding (Tropical Storm Allison)

Hazard-Related Deaths and Injuries

According to the NCDC, the City of Galveston has experienced at least 5 fatalities and 10 injuries from natural hazards in the period from 1950 – 2009.

6.3 Overview of the Type and Location of Hazards That Can Affect the City of Galveston

In the initial phase of the planning process, the City of Galveston's Hazard Mitigation Plan Stakeholder Committee (HMPSC) considered 28 natural and technological hazards and the risks they create for the City and its material assets, operations, and staff. The hazards initially considered are shown in Table 6.3-1.

Table 6.3-1
Preliminary Hazard List – City of Galveston

Preliminary Hazard List					
Hazard	**Type [1]**	**City's EOP**	**2009 County Update**	**2008 State of Texas HMP [2]**	**Include in City HMP**
Aircraft Incident	T				
Biological Event	T / N	✓			✓
Coastal Erosion	N			✓	✓
Coastal Retreat	N			✓	✓
Coastal Subsidence	N			✓	✓
Dam / Levee Failure	T		✓	✓	
Drought	N		✓	✓	✓
Earthquake[3]	N		✓	✓	
Environmental Disaster	T	✓			✓
Expansive Soils	N			✓	
Extreme Heat	N		✓	✓	
Extreme Wind	N				✓
Flood[4]	N		✓	✓	✓
Hailstorm	N		✓	✓	
Hazardous Material Incident (Fixed Site and Transport)	T	✓	✓		✓
Hurricane	N		✓	✓	
Land Subsidence	N			✓	
Landslide	N				
Lightning	N				✓
Mosquito-Borne Disease/Communicable Disease/Pandemic	N	✓			
Sea Level Change	N				✓
Severe Winter Storm	N		✓	✓	
Terrorism	I	✓			✓
Thunderstorm (as Windstorm)	N			✓	
Tornado	N		✓	✓	
Tsunami	N		✓		✓
Volcano	N				
Wildfire / Urban Fire	N	✓	✓	✓	✓

Notes:
1. Type Legend: I = Intentional Acts; N = Natural; T = Technological / Manmade
2. Included in 2008 State of Texas HMP Hazard Profile.

3. Earthquake / Geological includes effects of surface faulting, ground shaking, earthquake induced landslides and liquefaction.
4. Flood includes flash, sheet, and coastal flooding

In the initial identification process, the City of Galveston HMPSC considered potential hazards to identify those with the most chance to significantly affect the City. The hazards include those that have occurred in the past and may occur in the future. A variety of sources were used to develop the list of hazards considered by the HMPSC. These included national, regional, and local sources such as emergency operations plans, the State of Texas Hazard Mitigation Plan, the Galveston County Hazard Mitigation Plan, FEMA's *How-To Series,* websites, published documents, databases, and maps, as well as discussion among the HMPSC members.

The HMPSC participated in an exercise regarding the types of hazards that have the potential threaten the City. To kickoff this initial exercise, the HMSC reviewed a worksheet outlining the hazards identified in the County's Plan Update and the State of Texas HMP, and additional hazards they could consider for inclusion in this Plan, including those discussed in FEMA 386 and the City's Emergency Operations Plan. They were asked to review the worksheet and to provide comments on the hazards they believed should be included in this Plan. The HMPSC reviewed the 28 hazards and determined that 14 posed the greatest threat to the City of Galveston. The HMPSC held discussions on each of the hazards, and was able to come to consensus on the disposition of each hazard. After these discussions and reviews, the following hazards were selected for inclusion in the Plan by the HMPSC:

1. Biologic Event
2. Coastal Erosion
3. Coastal Retreat
4. Coastal Subsidence
5. Drought
6. Environmental Disaster
7. Extreme Wind Event (includes Straight Line, Tornado and Hurricane Wind)
8. Flooding
9. Hazardous Materials Incident (Fixed Site and Transport)
10. Lightning
11. Sea Level Rise
12. Terrorism
13. Tsunami
14. Wildfire / Urban Fire

The following section profiles each of the 14 hazards listed above and includes a description of the hazard, location and extent of the hazard, severity of the hazard, impact on life and property, past occurrences of the hazard, and the probability of future occurrences of the hazard.

6.3.1 Biological Event

Description of the Biological Event Hazard

Biological hazards, also known as biohazards, refer to biological substances that pose a threat to the health of living organisms, primarily that of humans. This can include medical waste or samples of a microorganism, virus or toxin (from a biological source) that can impact human health. It can also include substances harmful to animals. The term and its associated symbol are generally used as a warning, so that those potentially exposed to the substances will know to take precautions.

For the purposes of this hazard profile, biological events refer to those events that are accidental or naturally occurring. Intentional transmission of infectious agents is included in the profile for terrorism.

Location of the Biological Event Hazard

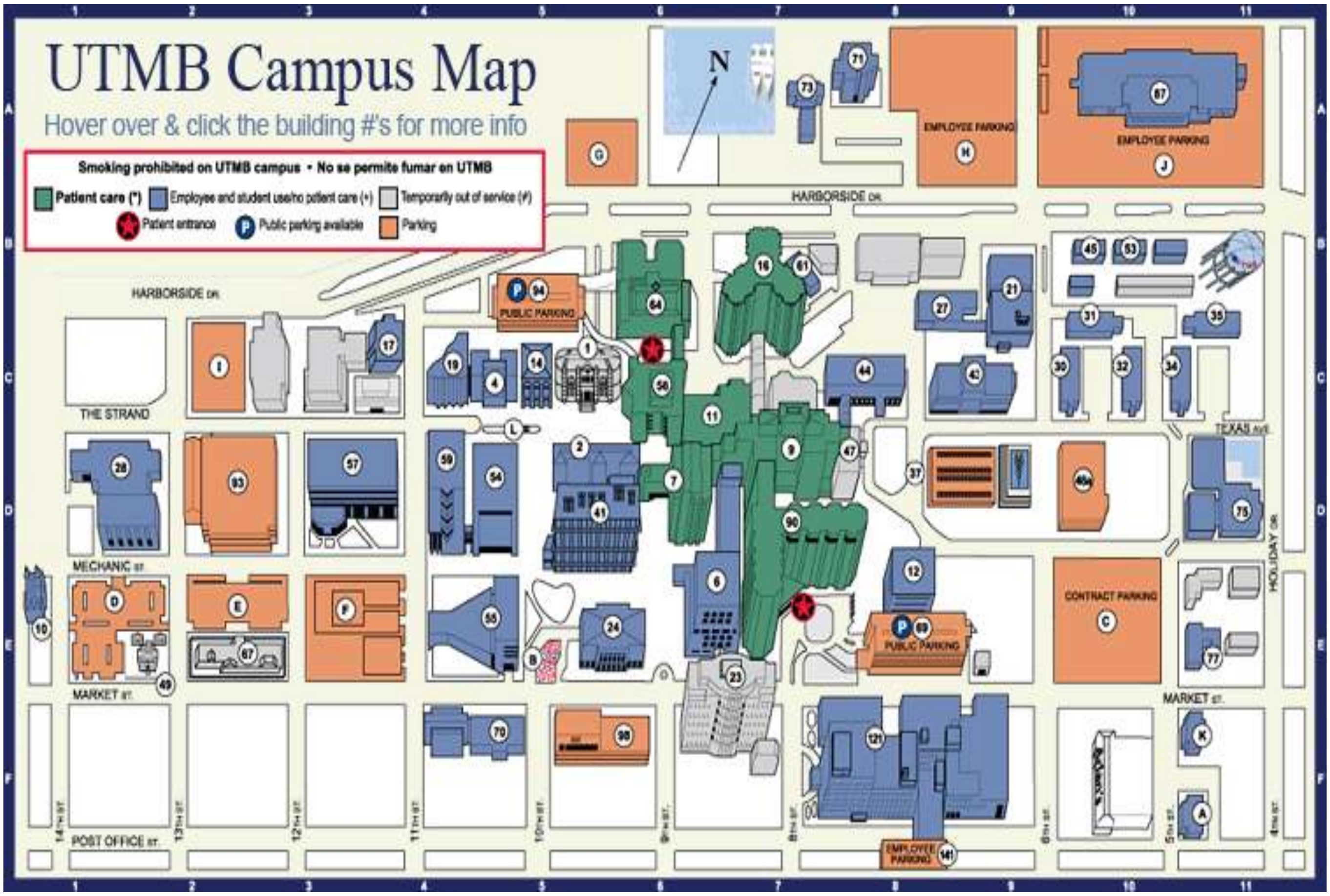
Biological events are non-spatial, unless an effective quarantine can be established. All locations within the City of Galveston are potentially at risk from this hazard.

Galveston is home to the University of Texas Medical Branch, which is a full service medical campus. In addition, UTMB also conducts medical research; many research applications involve the use of live animals. In support of infectious disease research, UTMB has safely operated several large suites of BSL-3 and Animal BSL (ABSL) laboratories for several years. UTMB currently operates a suite of eight BSL-3 laboratories comprising a total of over 5,200 feet^2 and 2,400 feet^2 of ABSL-3 laboratories within the Keiller Building. The Keiller Building is home to the UTMB's Center for Biodefense and Emerging Infectious Diseases and the Pathology Department. Located between the Keiller Building and Gail Borden Building is the John Sealy Pavilion for Infectious Diseases Research, containing the Robert E. Shope BSL-4 Laboratory, a 2,100 foot^2 BSL-4 facility. In addition, UTMB houses one of the most complete reference collections of bacteria, fungi, and viruses.

UTMB is also home to the Galveston National Lab (GNL), one of two National Biocontainment Laboratories. GNL contains BSL-4 labs. GNL maintains research space and capabilities to develop therapies, vaccines and diagnostic tests for both naturally occurring and human-created emerging diseases, such as SARS, West Nile encephalitis, and avian influenza.

Map 6.3.1-1 shows the campus of UTMB. Buildings in green are patient care facilities, which routinely contain biohazards. Building 41, located to the left of the patient care complex, is the Galveston National Lab.

Map 6.3.1-1
UTMB Campus Map
(Source: UTMB)

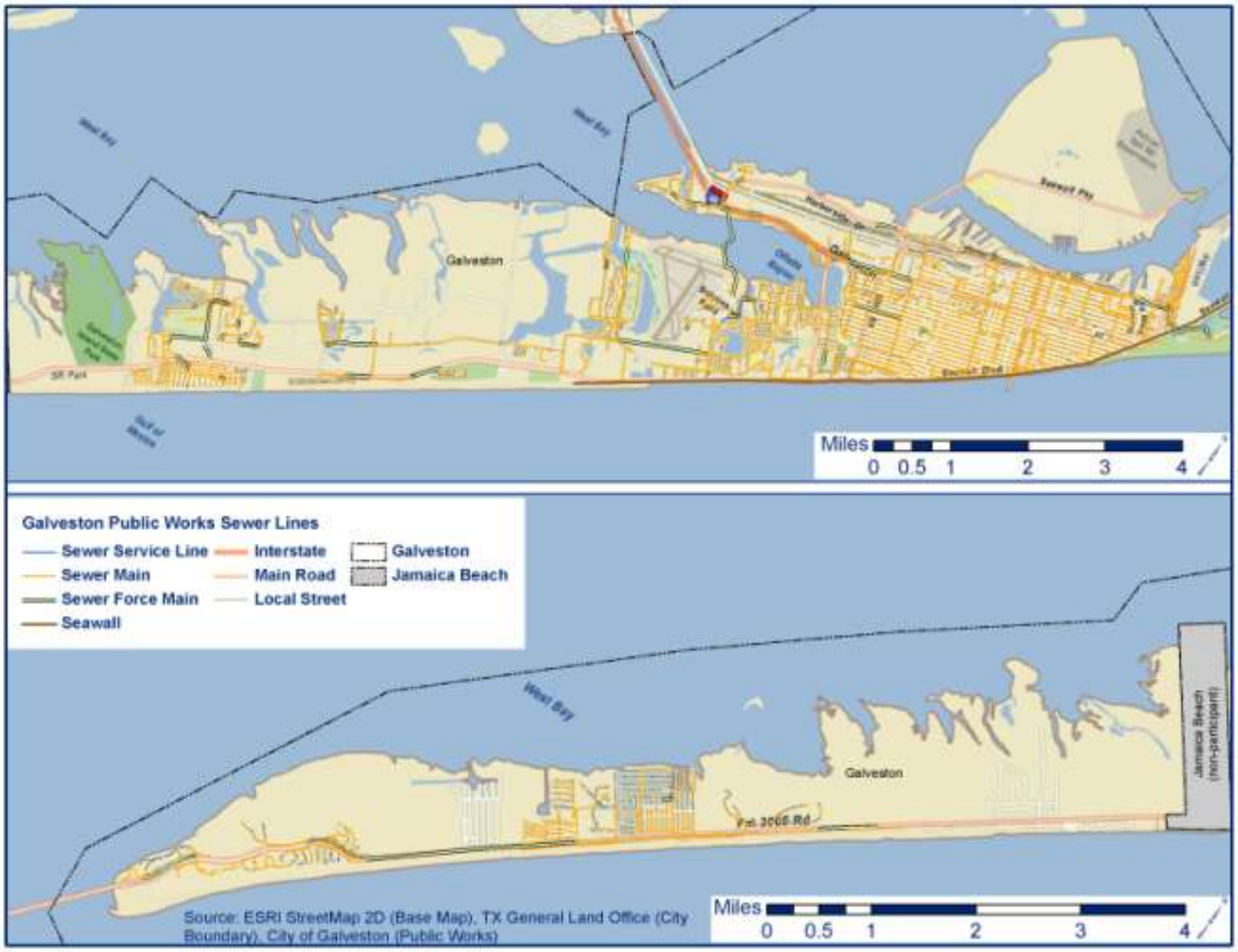


Map 6.3.1-2 shows the placement of the UTMB campus within the City of Galveston.

Map 6.3.1-2
Location of UTMB Campus Within City of Galveston
(Source:

In addition, the City of Galveston is home to thousands of miles of sewer pipe, which contain millions of gallons of untreated sewage prior to transport to sewage treatment facilities. Map 6.3.1-3 shows the locations of these pipes.

Map 6.3.1-3
Location of Sewer Pipes – City of Galveston
(Source: ESRI, GLO, City of Galveston)



Severity of the Biological Event Hazard

The United States' Centers for Disease Control and Prevention (CDC) categorizes various diseases in levels of biohazard, Level 1 being minimum risk and Level 4 being extreme risk.

- **Biohazard Level 1:** Bacteria and viruses including *Bacillus subtilis*, canine hepatitis, *Escherichia coli (E. Coli)*, varicella (chicken pox), as well as some cell cultures and non-infectious bacteria. At this level precautions against the biohazardous materials in question are minimal, most likely involving gloves and some sort of facial protection. Usually, contaminated materials are left in open (but separately indicated) waste receptacles. Decontamination procedures for this level are similar in most respects to modern precautions against everyday viruses (i.e.: washing one's hands with anti-bacterial soap, washing all exposed surfaces of the lab with disinfectants, etc). In a lab environment, all materials used for cell and/or bacteria cultures are decontaminated via autoclave.

- **Biohazard Level 2:** Bacteria and viruses that cause only mild disease to humans, or are difficult to contract via aerosol in a lab setting, such as hepatitis A, B, and C, influenza A, Lyme disease, salmonella, mumps, measles, scrapie, dengue fever, and HIV. Routine diagnostic work with clinical specimens can be done safely at Biosafety Level 2 (BSL-2), using BSL- 2 practices and procedures. Research work (including co-cultivation, virus replication studies, or manipulations involving concentrated virus) can be done in a BSL-2 facility, using BSL-3 practices and procedures. Virus production activities, including virus concentrations, require a BSL-3 facility and use of BSL-3 practices and procedures.

- **Biohazard Level 3:** Bacteria and viruses that can cause severe to fatal disease in humans, but for which vaccines or other treatments exist, such as anthrax, West Nile virus, Venezuelan equine encephalitis, SARS virus, variola virus (smallpox), tuberculosis, typhus, Rift Valley fever, Rocky Mountain spotted fever, yellow fever, and malaria. Among parasites *Plasmodium falciparum*, which causes Malaria, and *Trypanosoma cruzi*, which causes trypanosomiasis, also come under this level.

- **Biohazard Level 4:** Viruses and bacteria that cause severe to fatal disease in humans, and for which vaccines or other treatments are *not* available, such as Bolivian and Argentine hemorrhagic fevers, H5N1(bird flu), Dengue hemorrhagic fever, Marburg virus, Ebola virus, hantaviruses, Lassa fever, Crimean-Congo hemorrhagic fever, and other hemorrhagic diseases. When dealing with biological hazards at this level the use of a Hazmat suit and a self-contained oxygen supply is mandatory. The entrance and exit of a Level Four biolab will contain multiple showers, a vacuum room, an ultraviolet light room, autonomous detection system, and other safety precautions designed to destroy all traces of the biohazard. Multiple airlocks are employed and are electronically secured to prevent both doors opening at the same time. All air and water service going to and coming from a BSL- 4 lab will undergo similar decontamination procedures to eliminate the possibility of an accidental release.

The Center for Disease Control and Prevention (CDC) determines the severity of pandemics and communicable disease outbreaks based on a measurement system is known as the Pandemic Severity Index. The index focuses less on how likely a disease will spread worldwide-that is, become a pandemic-and more upon how severe the epidemic actually is. The main criterion used to measure pandemic severity will be case-fatality ratio (CFR), the percentage of deaths out of the total reported cases of the disease.

The analogy of "category" levels was introduced to provide an understandable connection to hurricane classification schemes, with specific reference to the recent aftermath of Hurricane Katrina. Like the Saffir-Simpson Hurricane Scale, the PSI ranges from 1 to 5, with Category 1 pandemics being most mild (equivalent to seasonal flu) and level 5 being reserved for the most severe "worst-case" scenario pandemics (such as the 1918 Spanish flu).

Table 6.3.1-1
Centers for Disease Control and Prevention Pandemic Severity Index
(Source: CDC)

Centers for Disease Control and Prevention Pandemic Severity Index		
Category	**Case Fatality Ratio**	**Example(s)**
1	less than 0.1%	Seasonal Flu and Swine Flu
2	0.1% to 0.5%	Asian Flu and Hong Kong Flu
3	0.5% to 1%	No examples provided
4	1% to 2%	No examples provided
5	2% or higher	Spanish flu

Given that Galveston is a coastal community with a high number of visitors and tourists (who arrive by car, air and cruise ship), and given that the population is concentrated on the eastern third of the island, Galveston could expect to experience the entire range of an outbreak's severity.

Impact on Life and Property from the Biological Event Hazard

Biological events will have the most immediate impact on life. The extent of the impact will be contingent on the type of infection or contagion, the severity of the outbreak, and the speed at which it is transmitted. Property and infrastructure could be affected if large portions of the population were affected and unable to perform maintenance and operations tasks. For example, if a large percentage of workers are impacted, business, government and industry could have depressed productivity and activity. This could lead to economic impacts and disruption in the City, and could have a ripple effect to surrounding areas.

In case of a severe weather condition, operating procedures at the GNL facility call for a lockdown of all infectious material and decontamination of high-level biocontainment laboratories in the event of an approaching hurricane. Storm preparedness is based on approximately 24-hour notice of probable landfall, taking into account the predicted strength of a storm. This allows sufficient time to close down high containment operations, should this be deemed necessary, including the management of animals.

Occurrences of the Biological Event Hazard

Occurrences of the biological event hazard are fairly common. In recent history, there have been a number of *E. coli* and S*almonella* outbreaks traced to issues or deficiencies in the nation's food supply, or to particular restaurants or chains. Recent mutations in the influenza virus resulted in the World Health Organization (WHO) declaring H1N1 to be a global pandemic.

In Texas, there have been several occurrences of biological hazards, as reported by the CDC. In 2005, there were cases of dengue fever reported in South Texas, near the border with Mexico. Also in 2005, in the Houston area, approximately 1,100 evacuees from Hurricanes Katrina and Rita were infected with norovirus. During the winter of 2009 and early spring of 2010, 429 cases of the mumps were reported in the greater Houston area.

Galveston is a port for cruise ships, and there has been at least one instance involving passengers becoming ill while on the ship. The outbreak was isolated, but could have spread if not detected in time.

In Galveston, UTMB has been conducting research on emerging infectious diseases and biodefense for more than two decades. UTMB's biodefense research infrastructure includes all levels of biosafety laboratories with the recent addition of a 2,100 $foot^2$ BSL-4 laboratory, the John Sealy Pavilion for Infectious Diseases Research. Safety is a major concern in working with, and preventing the spread of, highly infectious disease agents. UTMB's safety records for its BSL-3 containment facilities from May 2002 to May 2004 indicate that there have been two animal bites but no infection. One animal bite was from a clean animal, and the other from an animal that was exposed to the West Nile Virus. Additionally, there have been no animal escapes from UTMB's biocontainment laboratories.

There are five potential pathways for infectious agents to leave biocontainment areas and to possibly cause human health effects. These pathways include direct transmission, vector-borne transmission, vehicle-borne transmission, airborne transmission, and waterborne transmission. UTMB has developed the necessary policies and procedures (e.g., L*aboratory Security and Safety Plan for Laboratories Working with Select Agents, Biological Safety Manual and Standard Operating Procedures for Keiller Building BSL-3 Facility, and Biosafety Manual Robert E. Shope, MD BSL-4 Laboratory Policies and Procedures*) that are applied to all facilities that handle biohazards during operations. These policies and procedures, coupled with adequate and appropriate worker training and adherence to NIH, CDC, USDHHS, and other standards, guidelines, and procedures for biocontainment facility operation significantly reduce any threat to worker and public health and safety. In the unlikely event of a biocontainment breach, the public would be notified through a coordinated effort involving Federal, state, and local agencies.

Probability of Future Occurrences of the Biological Event Hazard

While a high concentration of biohazards does exist in the City of Galveston, all required containment measures and plans are in place for such an event. The likelihood of such an event occurring and impacting the community is low. It is more likely that a naturally occurring infection would have a larger impact, and is more likely to occur. Therefore, the probability of future occurrence of a biohazard event is Moderate.

6.3.2 Coastal Erosion

Description of the Coastal Erosion Hazard

Coastal erosion is a hydrologic hazard, and is defined by the wearing away of land or the removal of beach or dune sediments by wave action, tidal currents, wave currents, or drainage. Waves, generated by storms, wind, or fast moving motor craft, cause coastal erosion, which may take the form of long-term losses of sediment and rocks, or merely the temporary redistribution of coastal sediments. Erosion in one location may result in accretion nearby. Coastal erosion may result from a natural process, or it may be the result of human action.

On rocky coasts, coastal erosion results in dramatic rock formations in areas where the coastline contains rock layers or fracture zones with different resistances to erosion. Softer areas become eroded much faster than harder ones, which typically result in landforms such as tunnels, bridges, columns, and pillars. On sedimentary coasts, coastal erosion typically poses more of a danger to human settlements than it does to nature itself.

Coastal erosion is episodic. Most erosion occurs over a short period, sometimes in hours during a hurricane, sometimes during a season as in California during an El Niño event. Coastal erosion is also sporadic. All areas of the shore are not eroded at the same rate during a storm. Some areas have severe erosion during an event. Other areas have much less erosion. Some areas constantly and rapidly erode. The Mississippi Delta region in Louisiana is a major example. Some areas erode many feet per year. Other areas, such as the rocky Pacific Coast, erode at a rate of inches per year.

Coastal erosion can be classified as either long-term or short-term, depending on the time over which it occurs. Long-term erosion usually refers to a trend of erosion extending over several years and can be caused by a deficit in the annual sediment budget or in the longshore transport rates along the beach. It is possible for this type of erosion to occur without any significant impact to the beach's natural system if the beach profile is not changed by development but merely shifted landwards.

Short-term erosion refers to erosion occurring over a period of days because of extreme weather events such as severe storm or hurricane activity. Short-term erosion results in sudden and abrupt changes to the profile of the beach. During short-term erosion events, significant sand transport occurs offshore. After the storm passes, normal beach processes usually produce onshore sand transport, restoring the beach naturally. This natural restoration process may take many months or years. In some cases, intervention to restore the beach to its former condition is not required. The effect of severe hurricanes; however, may last for decades and can result in relatively permanent features such as relocated tidal entrances.

Coastal erosion is a natural phenomenon of beaches. Beaches respond to environmental factors such as annual variations in the amount of sand washed down from rivers, changes in river delta channels, and changes in the weather, especially prevailing winds, severe storms and hurricanes. The beach profile that is affected by the physical process of erosion extends from the top of the dune system to a nearshore point seaward of the intertidal zone. As environmental conditions change, the profile changes as sand is moved onshore or offshore. The movement of sand may appear as beach erosion, beach accretion, dune build-up, or the formation of sand bars.

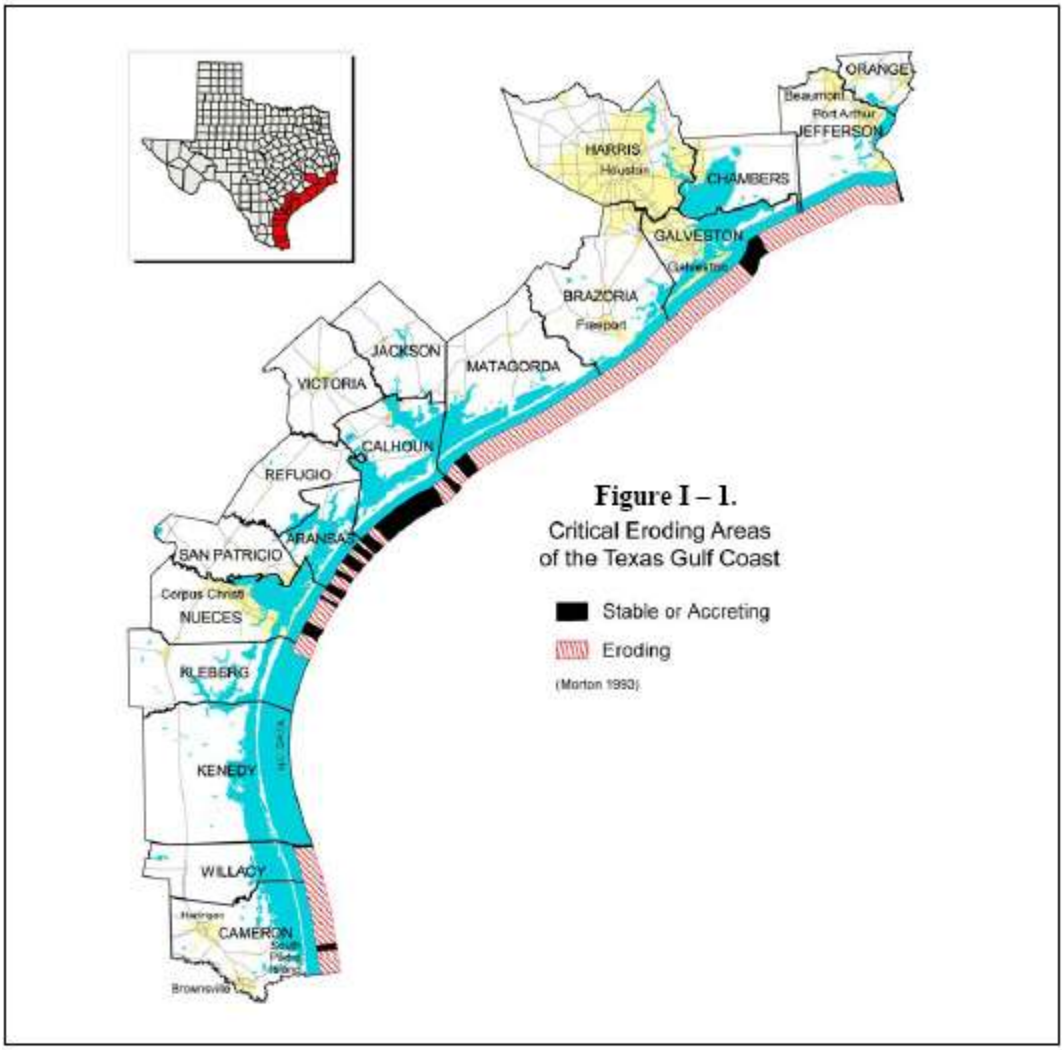
These changes are commonly temporary due to ever-changing environmental conditions. However, in some cases there may be a trend of ongoing erosion, resulting in long-term shoreline recession. This is the case in 63% of Texas' coastline.

Location of the Coastal Erosion Hazard

As a barrier island with almost 30 miles of Gulf-facing beach, and a similar amount of Bay-facing shoreline, Galveston has a history of coastal erosion. All shoreline areas of Galveston have the potential to experience erosion.

Figure 6.3.2-1 illustrates the areas of the Texas Gulf Coast, and indicates which are eroding and which are stable or accreting. It should be noted that this figure is intended to show long-term erosion rates, and contains pre-Ike data.

Figure 6.3.2-1
Areas of Coastal Erosion along the Texas Gulf Coast, 2007
(Source: Texas General Land Office)

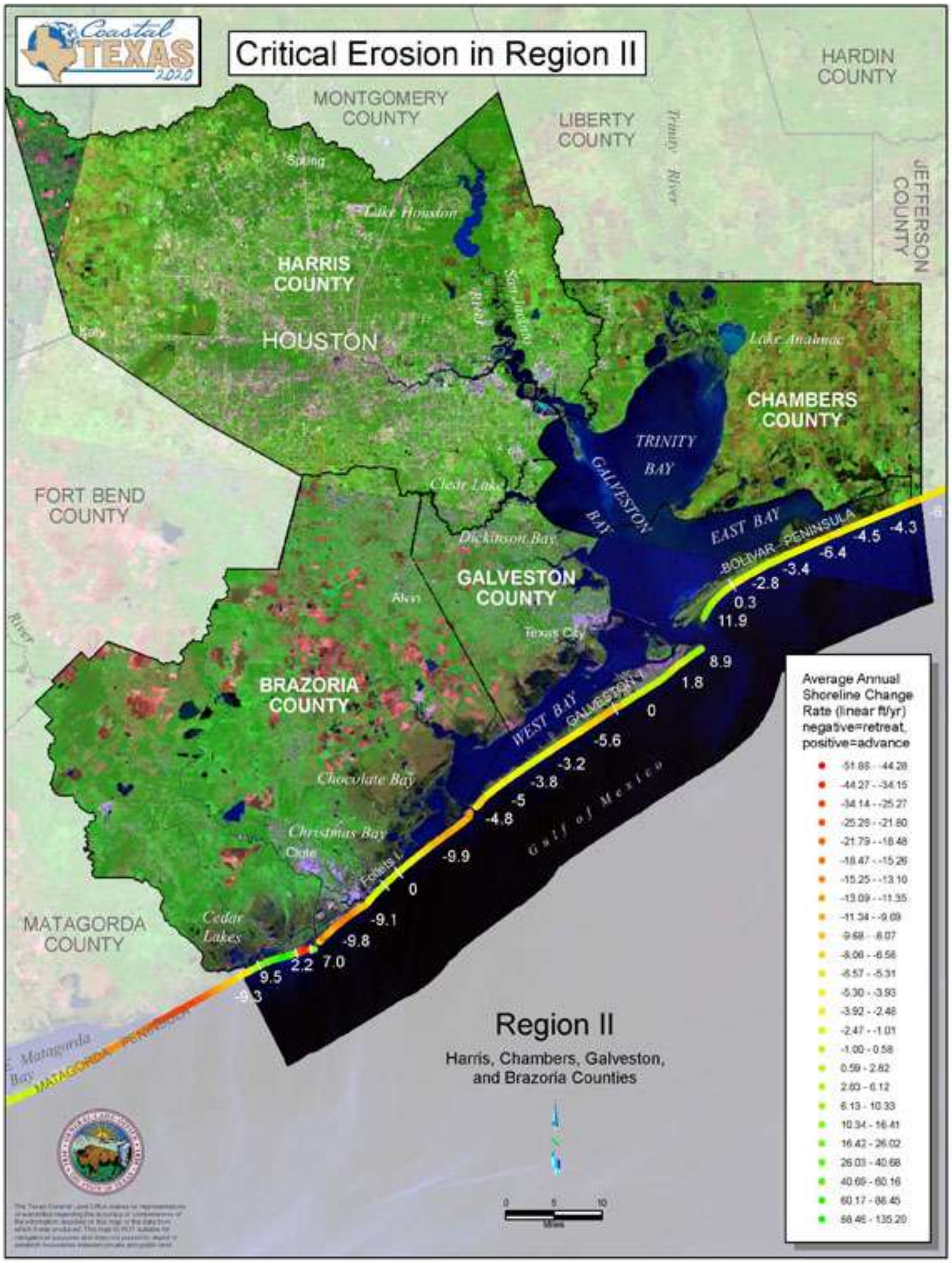


As evident in the figure above, the extreme eastern end of Galveston Island trends more towards stable or accreting, whereas the western end of the island is experiencing erosion.

Severity of the Coastal Erosion Hazard

Coastal erosion is measured as a rate, in terms of either linear feet (i.e., the feet of shoreline recession per year) or as volumetric loss (i.e., cubic yards of eroded sediment per linear foot of shoreline frontage per year). Map 6.3.2-1 shows the rate of coastal erosion in Galveston County, in terms of linear feet per year.

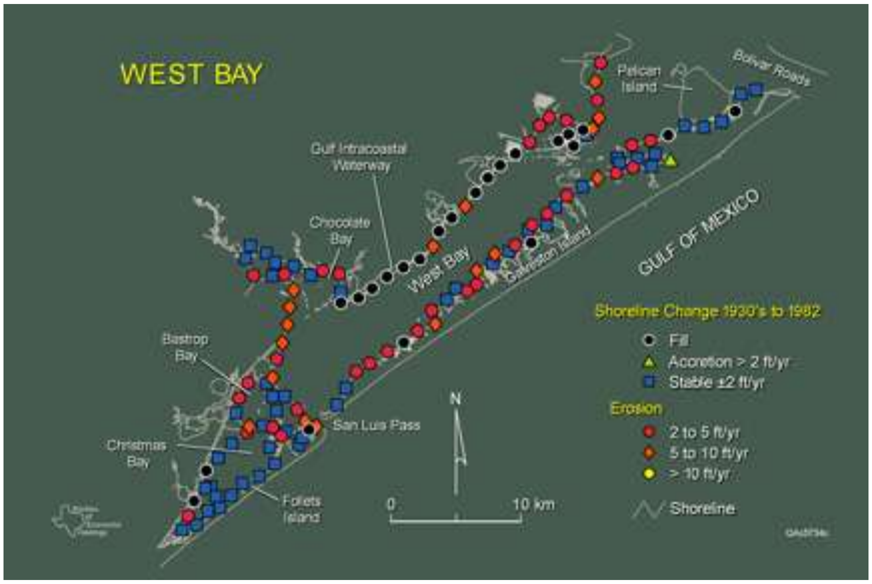
Map 6.3.2-1
Shoreline Change Rates along Upper Texas Gulf Coast
(Source: Texas General Land Office)



Note that the above map is based on pre-Ike data.

Figure 6.3.2-2 below shows the shoreline changes in the West Bay over time. Rates of erosion are indicated in terms of feet per year.

Figure 6.3.2-2
West Bay Shoreline Changes from 1930s-1982
(Source: Texas General Land Office, Bureau of Economic Geology, UT – Austin)



As shown in this figure, Bay-facing areas on the eastern end of the island and on the extreme western end appear to be stable. This means that they are eroding at a rate of less than 2 feet per year. The more central Bay-facing areas of the island are experiencing erosion at rates between 2 and 10 feet per year.

According to the Texas Commission on Environmental Quality, the State agency charged with wetlands conservation and protection, from the early 1950s to 1989, Galveston Bay lost nearly 35,000 acres (20%) of its wetlands. By some estimates, more than 22 acres of wetlands – areas vital to protecting the island from storm and tidal surges – have been lost to erosion in recent years alone.

According to the Texas General Land Office, portions of Galveston are experiencing fairly significant coastal erosion, while other areas are either stable or accreting. Each coastal storm event only increases the erosion that is otherwise occurring, and has the potential to alter the stability or accretion rates of other areas. Depending on the specific location and the circumstances, Galveston could expect to experience all situations, from severe erosion to accretion.

Impact on Life and Property from the Coastal Erosion Hazard

Coastal erosion and the efforts taken to alleviate it have a huge affect upon both the infrastructure and the economies that support the increasing coastal population. The processes that cause erosion are interrelated and can have a compounding affect upon one another. Several contributing factors to coastal erosion in Texas are influenced by human activity:

- Dams on the major rivers have reduced the volume sand and sediment from reaching the Gulf coast;

- Rivers have been diverted to better develop shipping lanes, resulting in critical erosion of nearby communities and land, as well as shoaling, flooding, and safety issues in other areas;
- Navigation structures such as jetties and dikes have changed the way sand moves along the coast, eroding down-drift shorelines;
- Maintenance dredging of navigation channels has taken sand and sediment out of the littoral system;
- Seawalls, groins, and other protective structures have caused erosion of down-drift beaches and shorelines;
- Wakes, surges, and waves from boats, ships, barges, and other vessels have eroded shorelines adjacent to navigation channels;
- Groundwater and petroleum extractions are causing land subsidence and subjecting large regional areas of coastal land to be converted to open water; and
- Wetland loss from dredging and filling to accommodate development has reduced the wetlands' ability to buffer erosion effects from winds and waves.

Erosion of coastal Texas negatively affects the state's economy, damages natural resources, and threatens the health and safety of millions of Texans and visitors, including closure and flooding of roads used for hurricane evacuations. Erosion damage to the beach dune system has occurred along the Texas Gulf coast, compromising the integrity of this natural defense against hurricane surges and other severe storm impacts.

Approximately 30,000 commercial fishermen catch almost 100 million pounds of coastal fish and shellfish annually, with an estimated value of approximately $270 million. The total economic contribution to the state's economy from the nearly 850,000 sport fishermen is over $2 billion per year.

Coastal habitats attract 40,000 coastal waterfowl hunters, photographers, swimmers, campers, bird-watchers, boaters, and sightseers, generating an additional $3 billion per year.

Coastal destinations account for 30% of travel in Texas, which equates to some $10 billion per year. The City of Galveston, as just such as destination, is financially dependent upon the tourism dollars that their beaches generate. Coastal wetlands crucial to fish and waterfowl populations are increasingly impacted by erosion and conversion to open water.

Texas coastal industries depend on the Gulf Intra-Coastal Water Way (GIWW) and the major Texas ports for import of raw materials and export of products. Overwhelmingly, Texas coastal industry is petrochemical-based. Among the planned expansions for Texas coastal industry are nine liquid natural gas facilities. Navigation structures (e.g., jetties and dikes) and Operation and Maintenance (O&M) practices protect and maintain the waterways for commerce, but have the unintended consequence of causing erosion of adjacent shorelines. Additionally, vessel wakes, surges, and waves are among the causes of erosion of Texas coastal land. The growth of industry and expansion of shipping will only exacerbate the erosion unless coastal erosion response projects are completed in several key areas.

The GIWW extends 426 miles along the Texas Gulf Coast and links Texas's deep-water ports. The GIWWW provides the state's oil, chemical, and mining industries direct access to important Midwestern markets and plays a vital economic role in Texas.

Occurrences of the Coastal Erosion Hazard

On average, 235 acres per year of land along the Texas gulf coast and land along the state's bays, estuaries, and navigation channels is lost due to erosion. Sixty-three percent of the Texas Gulf shoreline has an historical erosion rate of more than two feet per year, with some locations eroding more than 10 feet per year.

Table 6.3.2-1
Miles of Critically Eroding Shoreline in Texas
(Source: State HM Plan, Bureau of Economic Geology, Texas General Land Office)

Miles of Critically Eroding Shoreline in Texas, 2007			
Region	**Total Coastline Miles**	**Critically Eroding Miles**	**Percent of Shoreline Eroding**
Sabine Pass to Bolivar Road (Galveston County)	59.0	47.0	80%
Bolivar Roads to San Luis Pass	29.0	27.0	93%
San Luis Pass to Old Colorado River	63.1	63.1	100%
Old Colorado River to Aransas Pass	83.7	38.5	46%
Aransas Pass to Padre Island National Seashore	27.3	15.3	56%
Padre Island National Seashore to Mansfield Cut	64.1	1.0	2%
Mansfield Cut to Rio Grande River (U.S. / Mexico Border)	40.8	37.5	92%
Totals:	**367.0**	**229.4**	**63%**

Galveston experienced significant beach erosion from Hurricane Ike, as evident in Figure 6.3.2-3 below. These photographs are of structures at the eastern end of Galveston Island, and are Gulf-facing.

Figure 6.3.2-3
Evidence of Short-Term Erosion Following Hurricane Ike – Eastern End
(Source: USGS)

As is evident in these before-and-after photographs, the short-term coastal erosion experienced during Hurricane Ike was extensive. Note also the complete loss of natural vegetation and dune systems.

These photographs are of structures on the West End of Galveston Island, and are Gulf-facing. They also show significant loss of beach, vegetation and dune systems.

Figure 6.3.2-4
Evidence of Short-Term Erosion Following Hurricane Ike – West End
(Source: USGS)

Probability of Future Occurrences of the Coastal Erosion Hazard

Given that coastal erosion is a naturally-occurring phenomenon, and given that Galveston is home to miles of shoreline, the probability of future occurrences of the coastal erosion hazard is High.

6.3.3 Coastal Retreat

Description of the Coastal Retreat Hazard

Coastal retreat is defined as any particular section of beach that is accreting or retreating as the result of a complex interaction between the conflicting forces of sediment deposition, tidal movement, the long-shore current and sand storage in dunes and bars.

Coastal retreat can be the result of coastal erosion, and can worsen the impacts of tropical systems and other coastal storms.

Location of the Coastal Retreat Hazard

Coastal retreat is occurring in portions of Galveston, most notably at Pier 15 at the Port of Galveston, and in places along the West End.

Map 6.3.3-1, produced by the Bureau of Economic Geology, illustrates the location of the coastline in 1956, 1996, and the projected location of the coastline by 2056. The location in this map is on the West End of Galveston.

Map 6.3.3-1
Galveston Coastal Retreat
(Source: Bureau of Economic Geology)

Severity of the Coastal Retreat Hazard

Currently, no scale exists to measure the severity of coastal retreat. The severity of the hazard is relative to the area in which is it occurring.

The following figure was obtained from a report issued by the USGS's National Wetlands Research Center, in Layfayette, LA. The graph illustrates a conceptual model of coastal retreat in relation to a 1 meter (3.28 feet) anticipated rise in sea level over the next century. Note the anticipated increased intrusion of saltwater into freshwater areas along the coast. Though this model is based on climate change characteristics, which are still a matter of debate among scientists, retreating coastlines and increases in sea level will result in increased saltwater intrusion in sensitive coastal areas.

Figure 6.3.3-1
Coastal Retreat and Sea Level Change
(Source: USGS)

As a Gulf Coast barrier island, Galveston could expect to experience coastal retreat at all levels of severity.

Impact on Life and Property from the Coastal Retreat Hazard

The impact on life and property from coastal retreat is similar, if not identical, to the impacts experienced from coastal erosion. Please see section 6.3.2 for details.

Occurrences of the Coastal Retreat Hazard

Some portions of Texas beaches are advancing and some are retreating. In general, the beaches are retreating. A substantial reduction of the width and breath of beaches, along with a reduction in dune structures, could allow hurricane driven storm surge to move further inland than what would otherwise be the case. A reduction in coastal marshes can have a similar effect.

In general, the State regards this as a minor threat. In the areas seaward of most major Texas coastal cities, the beach/coastal marsh is stable or accreting.

Probability of Future Occurrences of the Coastal Retreat Hazard

Given that coastal retreat is a naturally-occurring phenomenon, and given that Galveston is home to miles of shoreline, the probability of future occurrences of the coastal retreat hazard is Moderate.

6.3.4 Coastal Subsidence

Description of the Coastal Subsidence Hazard

Coastal subsidence is defined as the loss of coastal surface elevation due to the removal of subsurface support.

Subsidence can be the result of both nature and human action. Some natural subsidence occurs over long periods of time, due to the natural settling process of millions of year's accumulation of sediments.

The vast majority of subsidence is caused by human action, however. In the Houston – Galveston area of coastal Texas, much of the coastal subsidence has occurred as a result of the removal of groundwater. Large amounts of groundwater have been pumped from the aquifers beneath the area, allowing the clay to compact under the weight of the ground and built environment above it. In other parts of the world, subsidence is caused by oil and gas withdrawals and coal mining.

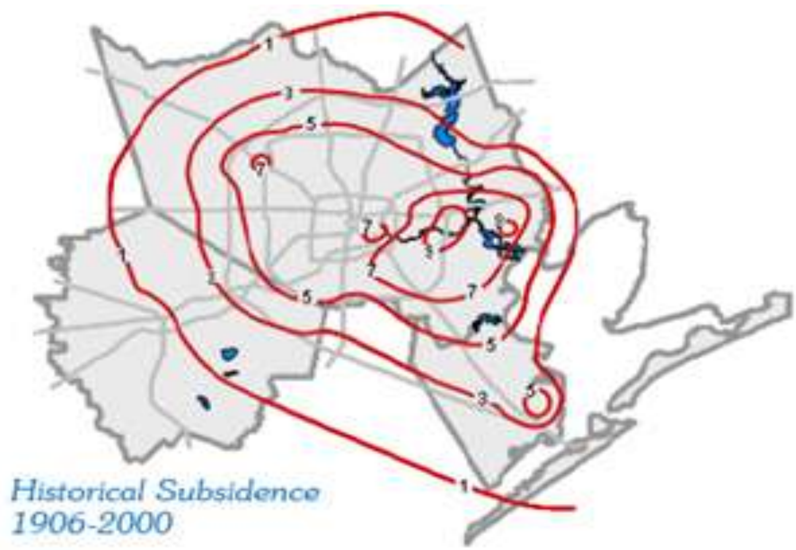
Subsidence is of particular concern in low lying coastal areas, where the land is already low in relation to the water. As the ground subsides, be it from natural or human action, the elevation of the land in relation to mean sea level becomes less and less, increasing the risk from and exposure to hazards associated with coastal storms and tropical systems. Further inland, the effects of subsidence are not as apparent, though the hazard does still exist.

Coastal subsidence is also of particular concern and can be particularly hazardous to those areas that are simultaneously experiencing changes in sea level. (NOTE: Sea Level Change is profiled as a separate hazard in this Plan. Please see section 6.3.11)

Location of the Coastal Subsidence Hazard

Coastal subsidence is a regional phenomenon, generally affecting large geographic areas. Map 6.3.4-1 shows the location of historical subsidence in the Greater Houston-Galveston area over the last century.

Map 6.3.4-1
Historical Subsidence in the Greater Houston-Galveston Area, 1906-2000
(Source: Harris Galveston Subsidence District)



Severity of the Coastal Subsidence Hazard

Currently, no scale exists to measure the severity of coastal subsidence. The severity of the hazard is relative to the area in which is it occurring.

For a barrier island like Galveston, any subsidence of the coastal area can be catastrophic. Galveston could reasonably expect to experience subsidence ranging from minimal depressions in the beach as a result of changes in the beach itself, almost unnoticeable to the average person, to severe, resulting in sinkhole-like formations with the potential to cause damage to nearby structures. At this time, limited data is available to quantify the extent and severity of the coastal subsidence hazard specific to Galveston. The City is hopeful that this data will be more forthcoming in the future, and can be incorporated into future updates of this plan.

As discussed in Section 3 of this Plan, approximately one-third of Galveston Island was raised after the 1900 Storm. As a result of this artificial elevation, the eastern third of the Island averages approximately 12-13 feet above mean sea level. This artificial elevation has provided some protection from subsidence, by providing more land mass.

The western two-thirds of the Island, which were not elevated after the 1900 Storm, average approximately 5-7 feet in elevation, relative to mean sea level. This unaltered elevation translates to less land mass, making the west end of Galveston more susceptible to coastal subsidence.

Impact on Life and Property from the Coastal Subsidence Hazard

Subsidence of coastal areas has the potential to be catastrophic to the City of Galveston, its assets and residents. The island is already subject to flooding, both from rainfall and from coastal storms. Any further decrease in elevation would only serve to worsen these conditions. This would lead to increases in property damage and threats to the health and safety of residents.

The anticipated impact to structures is expected to be minimal, unless the subsidence occurred underneath the structure or the supporting foundation. In this case, it's anticipated that there would be an impact to structures, and to the people who occupy them. Depending on the size of the area affected by the subsidence, this impact could be a range, from minimal to severe.

In addition, the City owns and maintains a great deal of horizontal infrastructure that is at risk from the impacts of coastal subsidence. This includes roads, water lines and sewer lines. Much of this infrastructure is in a state of temporary repair in the aftermath of Hurricane Ike, and is likely to remain so for a significant period of time. This temporary infrastructure is predominantly above-ground, while other infrastructure is slightly below grade, which is standard in this part of Texas.

Occurrences of the Coastal Subsidence Hazard

In the critical areas along Galveston Bay, the land surface has sunk as much as 10 feet since 1906, according to the Harris Galveston Subsidence District. Experts have been studying the subsidence phenomena for almost 100 years, and with each hurricane, subsidence and flooding problems worsen.

Simply put, subsidence will cease when communities cease pumping too much groundwater. However, the conversion from groundwater to alternative sources of water (surface water, treated effluent, etc.) is not as simple. Many of the cities, industries, and others in the coastal areas converted years ago to surface water, at considerable costs. This has had positive effects on this hazard and its consequences.

Probability of Future Occurrences of the Coastal Subsidence Hazard

According to the State Hazard Mitigation Plan, the rise in the creation of groundwater conservation districts, and their cousin, the coastal subsidence conservation districts, has largely eliminated the subsidence risk to coastal communities, including the City of Galveston.

Given that coastal subsidence is a naturally-occurring phenomenon, and given that Galveston is home to miles of shoreline – some of which are experiencing subsidence for a variety of reasons - the probability of future occurrences of the coastal retreat hazard is Moderate.

6.3.5 Drought

Description of the Drought Hazard

Drought is a normal part of virtually all climatic regions, including areas with high and low average rainfall. Drought is the consequence of anticipated natural precipitation reduction over an extended period of time, usually a season or more in length. Drought is one of the most complex of all natural hazards, as it is difficult to determine a precise beginning or end. In addition, drought can lead to or be exacerbated by other hazards, such as extreme heat or wildfires.

Droughts are classified as meteorological, hydrologic, agricultural and socioeconomic. Each of these classifications can be defined as follows:

- **Meteorological drought** is defined by a period of substantially diminished precipitation duration and/or intensity. The commonly used definition of meteorological drought is an interval of time, generally on the order of months or years, during which the actual moisture supply at a given place consistently falls below the climatically appropriate moisture supply.
- **Agricultural drought** occurs when there is inadequate soil moisture to meet the needs of a particular crop at a particular time. Agricultural drought usually occurs after or during meteorological drought, but before hydrological drought and can affect livestock and other dry-land agricultural operations.
- **Hydrological drought** refers to deficiencies in surface and subsurface water supplies. It is measured as stream flow, snow pack, and as lake, reservoir, and groundwater levels. There is usually a delay between lack of rain or snow and less measurable water in streams, lakes, and reservoirs. Therefore, hydrological measurements tend to lag behind other drought indicators.
- **Socio-economic drought** occurs when physical water shortages start to affect the health, well-being, and quality of life of the people, or when the drought starts to affect the supply and demand of an economic product.

Location of the Drought Hazard

Droughts can affect areas as small as a few counties to entire regions of the country. Droughts are not defined by a specific geographic boundary or location. The entire planning area is subject to the drought hazard. The City could also be severely impacted by droughts on the mainland, as all of their potable water originates from mainland sources.

Severity of the Drought Hazard

Droughts are measured using the Palmer Drought Severity Index (PDSI), also known as the Palmer Index. The Palmer Index was developed by Wayne Palmer in the 1960s and uses temperature and rainfall information in a formula to determine dryness. It has become the semi-official drought index.

The Palmer Index is most effective in determining long term drought—a matter of several months—and is not as good with short-term forecasts (a matter of weeks). It uses a 0 as normal, and drought is shown in terms of minus numbers; for example, -2 is moderate drought, -3 is severe drought, and -4 is extreme drought. At present, northern Virginia is at a -4.0 point; north central Maryland is at a -4.2 level, and southern Maryland is at least a -4 level.

The Palmer Index can also reflect excess rain using a corresponding level reflected by plus figures; i.e., 0 is normal, +2 is moderate rainfall, etc. At present, north central Iowa is at a +5.2 level, and parts of South Dakota are even higher.

The advantage of the Palmer Index is that it is standardized to local climate, so it can be applied to any part of the country to demonstrate relative drought or rainfall conditions. The negative is that it is not as good for short term forecasts, and is not particularly useful in calculating supplies of water locked up in snow, so it works best east of the Continental Divide.

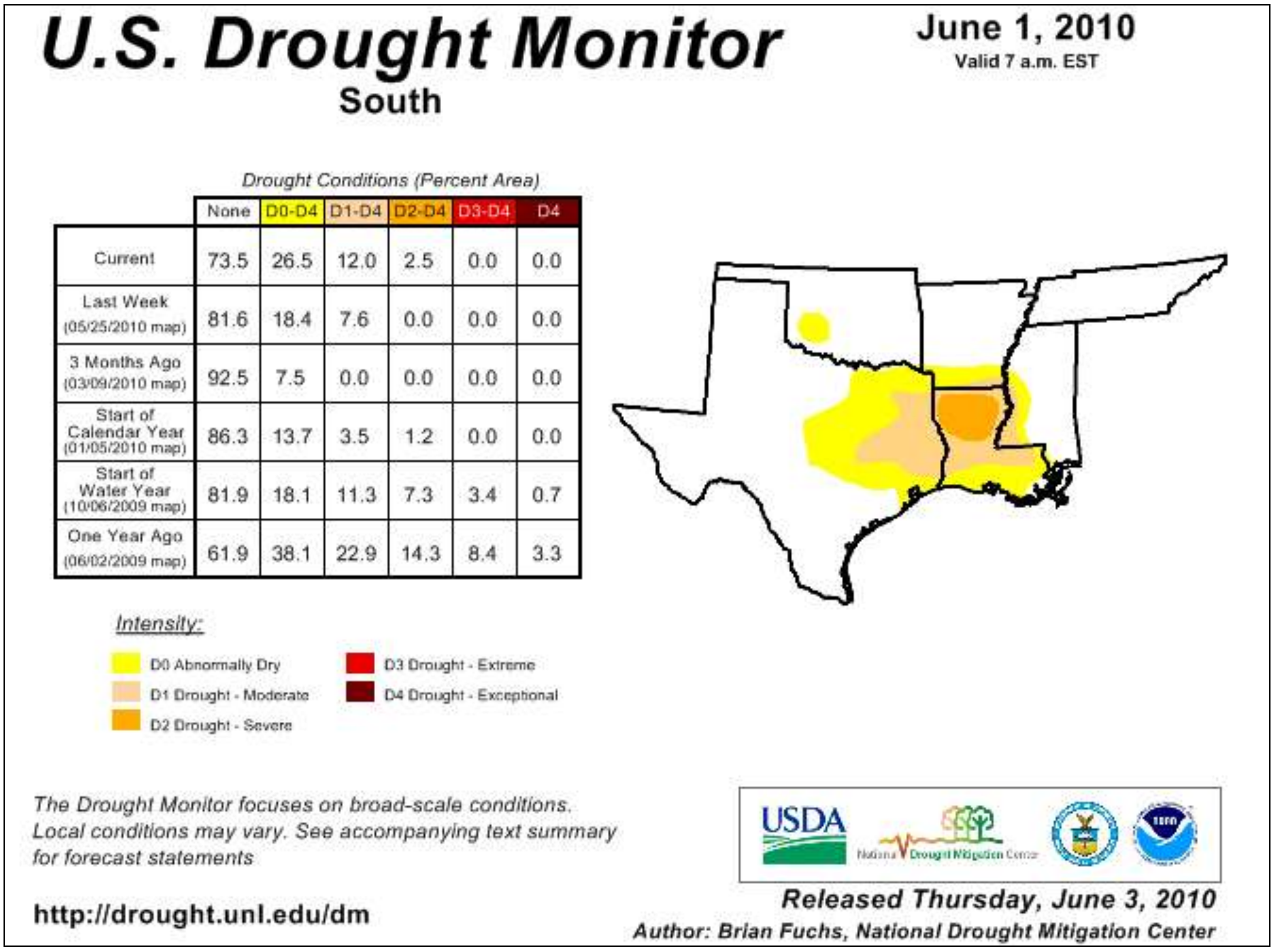
Table 6.3.5-1 illustrates the PDSI classifications.

Table 6.3.5-1
Palmer Drought Severity Index
(Source: http://drought.unl.edu/whatis/indices.htm)

Palmer Drought Severity Index	
Classification	**Description**
4.00 or more	Extremely wet
3.00 to 3.99	Very wet
2.00 to 2.99	Moderately wet
1.00 to 1.99	Slightly wet
0.50 to 0.99	Incipient wet spell
0.49 to -0.49	Near normal
-0.50 to -0.99	Incipient dry spell
-1.00 to -1.99	Mild drought
-2.00 to -2.99	Moderate drought
-3.00 to -3.99	Severe drought
-4.00 or less	Extreme drought

Drought is monitored nation-wide by the National Drought Mitigation Center (NDMC). Indicators are used to describe broad scale drought conditions across the country. Indicators correspond to the intensity of the drought. Portions of east Texas are currently experiencing abnormally dry to moderate drought conditions, as demonstrated by Figure 6.3.5-1 below.

Figure 6.3.5-1
US Drought Monitor - South
(Source: http://drought.unl.edu/dm/DM_south.htm)



	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	73.5	26.5	12.0	2.5	0.0	0.0
Last Week (05/25/2010 map)	81.6	18.4	7.6	0.0	0.0	0.0
3 Months Ago (03/09/2010 map)	92.5	7.5	0.0	0.0	0.0	0.0
Start of Calendar Year (01/05/2010 map)	86.3	13.7	3.5	1.2	0.0	0.0
Start of Water Year (10/06/2009 map)	81.9	18.1	11.3	7.3	3.4	0.7
One Year Ago (06/02/2009 map)	61.9	38.1	22.9	14.3	8.4	3.3

Galveston is subject to periodic dry spells, as is all of coastal Texas. Should a prolonged drought occur on the mainland or affect the source of potable water for the City, the City would experience the more sever effects of drought, even if local drought conditions were not severe.

Impact on Life and Property from the Drought Hazard

As illustrated by Figure 6.3.5-1 above, droughts can affect a large geographic area, and can range in size from a few counties to a few states. Their potential to impact wildlife and agricultural concerns can be enormous. Droughts can kill crops, edible plants and wildlife habitat, and destroy grazing lands and trees. Dead or dying vegetation, a normal result of drought, can then serve as a prime ignition source for wildfires.

Perhaps the best known example of the impacts on life and property from drought is the Dust Bowl. The phenomenon was caused by severe drought coupled with decades of poor farming and land management practices. Deep plowing of the virgin topsoil of the Great Plains killed the natural grasses that normally kept the soil in place and trapped moisture even during periods of drought and high winds.

During the (naturally occurring) drought of the 1930s, with no natural anchors to keep the soil in place, it dried, turned to dust, and blew away eastward and southward in large dark clouds. At times the clouds blackened the sky reaching all the way to East Coast cities such as New York and Washington, D.C. Much of the soil ended up deposited in the Atlantic Ocean, carried by prevailing winds which were in part created by the dry and bare soil conditions. These immense dust storms—given names such as "Black Blizzards" and "Black Rollers"—often reduced visibility to a few feet and produced deadly electrical storms. The Dust Bowl affected an estimated 100,000,000 acres, centered on the panhandles of Texas and Oklahoma, and adjacent parts of New Mexico, Colorado, and Kansas.

The Dust Bowl was an ecological and human disaster caused by misuse of land and years of sustained, naturally occurring drought. Millions of acres of farmland became useless, and hundreds of thousands of people were forced to leave their homes in order to survive.

The worst drought in 50 years affected at least 35 states during the summer of 1988. In some areas the lack of rainfall dated back to 1984. In 1988, rainfall totals over the Midwest, Northern Plains, and the Rockies were 50-85% below normal. Crops and livestock died and some areas became desert. Forest fires began over the Northwest, and by autumn 4,100,000 acres had burned. A government policy called "Let Burn" was in effect for Yellowstone National Park, with disastrous results. Half of the National Park - 2,100,000 acres - was charred when a huge forest fire developed.

For the City of Galveston, the impact of a drought could be enormous. As a barrier island, Galveston has no local source of potable water. All potable water must be purchased from mainland suppliers and transported to the island via a pipeline. In the event of a prolonged drought, it is possible that there would not be enough water available to the City to maintain its current pressure levels (and therefore to maintain the safety of the potable water system), or to support the population. Businesses and services that depend on water could be devastated, including fire and emergency services. Given the number of wood-frame structures in the City, a structure fire combined with limited water or water pressure conditions as a result of drought could be disastrous.

Drought has the potential to significantly affect special populations, including the elderly, children and tourists. In addition, a drought of a prolonged nature could have significant impacts on the City's ability to obtain and distribute potable water, which is required to sustain life, safety and health.

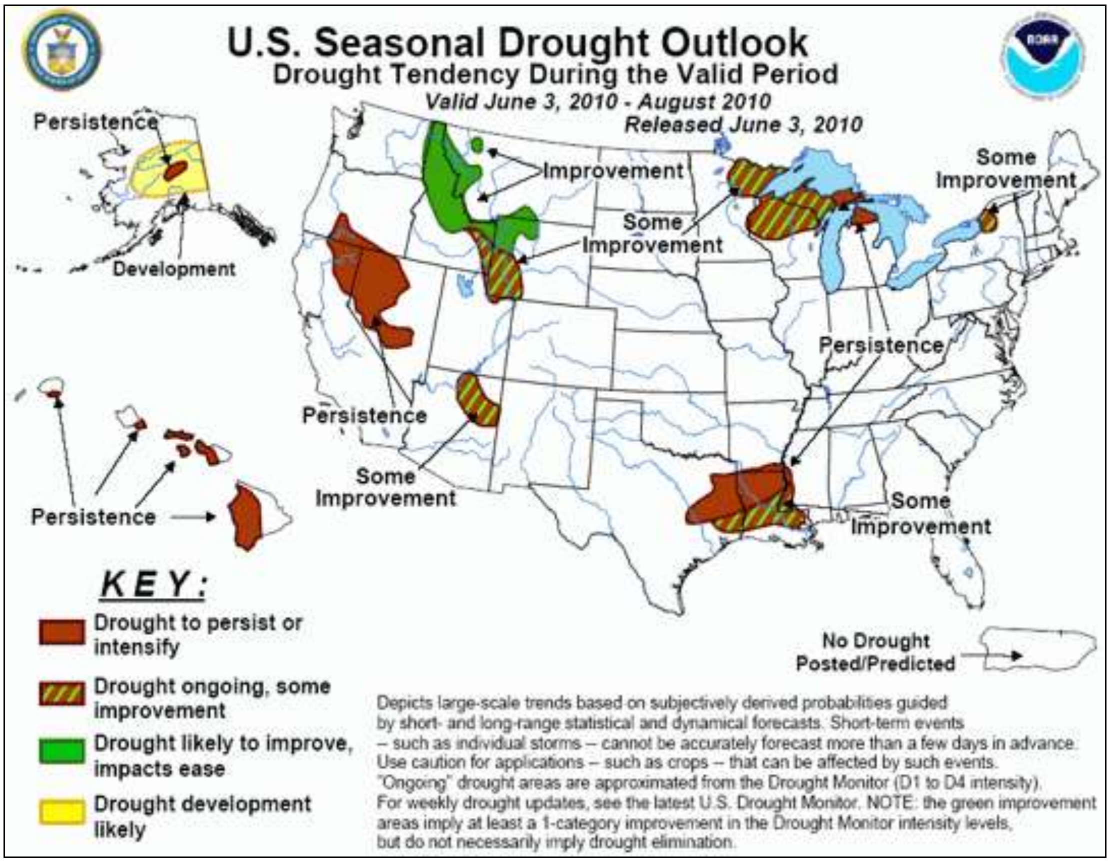
Occurrences of the Drought Hazard

The historic frequency of occurrence of drought for the Galveston area is occasional. Based on historical data, it can be expected that every 6 years Galveston County (the smallest unit for which data is available) will experience at least 1 drought season. Historical frequencies from 1895 to 1995 reveal that the entire Texas Gulf Coast Basin (which includes the City of Galveston) has suffered drought conditions at least every 10-20 years.

Probability of Future Occurrences of the Drought Hazard

The National Weather Service's Climate Prediction Center produces seasonal drought forecasts for the US. In their June 2010 forecast, they predict no occurrence of drought for the Galveston area, and improving conditions to the north of Galveston Island.

Figure 6.3.5-2
US Seasonal Drought Outlook
(Source: http://www.cpc.ncep.noaa.gov/products/expert_assessment/seasonal_drought.html)



Based on this data, the probability of future occurrence of the drought hazard can be classified as Low.

6.3.6 Environmental Disaster

Description of the Environmental Disaster Hazard

An environmental disaster is an incident which causes harm or negative consequences to the natural environment due to human activity. Environmental disasters may be exacerbated by natural phenomenon, but they do not originate from nature. While the actual harm that some environmental disasters may cause can be debated, the consequences to humans and to the built environment are rarely debatable.

Examples of environmental disasters include:

- **Habitat destruction** is the process in which natural habitat is rendered functionally unable to support the species present. In this process, the organisms which previously used the site are displaced or destroyed, reducing biodiversity. Habitat destruction by human activity mainly for the purpose of harvesting natural resources for industry production and urbanization. Clearing habitats for agriculture is the principal cause of habitat destruction. Other important causes of habitat destruction include mining, logging, and urban sprawl. Habitat destruction is currently ranked as the most significant cause of species extinction worldwide.
- **Land pollution** is the degradation of Earth's land surfaces often caused by human activities and the misuse of land resources. It occurs when waste is not disposed of properly. Health hazard disposal of urban and industrial wastes, extraction of minerals, and improper use of soil by inadequate agricultural practices are a few causes. Urbanization and industrialization are major sources of land pollution.
- An **oil spill** is an unintentional release of a liquid petroleum hydrocarbon into the environment due to human activity, and is a form of pollution. The term often refers to marine oil spills, where oil is released into the ocean or coastal waters. Oil spills include releases of crude oil from tankers, offshore platforms, drilling rigs and wells, as well as spills of refined petroleum products (such as gasoline) and their by-products, and heavier fuels used by large ships such as bunker fuel, or the spill of any oily refuse or waste oil. Spills may take months or even years to clean up. Oil also enters the marine environment from natural oil seeps. Most human-made oil pollution comes from land-based activity, but public attention and regulation has tended to focus most sharply on seagoing oil tankers.
- **Smog** is a kind of air pollution; the word "smog" is a hybrid of smoke and fog. Modern smog is a type of air pollution derived from vehicular emission from internal combustion engines and industrial fumes that react in the atmosphere with sunlight to form secondary pollutants that also combine with the primary emissions to form photochemical smog. Smog is also caused by large amounts of coal burning in an area caused by a mixture of smoke and sulfur dioxide.
- **Damage to underground septic tanks and systems** can lead to serious environmental contamination for local communities. Storm surge and other flooding events exert hydrostatic and hydrodynamic forces on the system, including the tanks, causing damage to the containment system, including leaking, seeping and – in some cases – can cause the tank itself to “pop” out of the ground. This leads to raw sewage contamination of both the land area and the surrounding waters.

Location of the Environmental Disaster Hazard

Environmental disasters can happen anywhere in or near Galveston. As a barrier island, the City is surrounded by Gulf and Bay waters. Any spill or incident in those waters will likely impact the City and its residents. Incidents on the mainland also have the potential to impact the City, depending on the incident type and weather conditions.

In addition, there are an unidentified number of individually-owned septic systems on the West End of Galveston Island. All septic systems are located west of the Seawall. These systems have caused environmental damage after being damaged by storm surge themselves. Currently, no map exists that illustrates the locations of these systems.

Severity of the Environmental Disaster Hazard

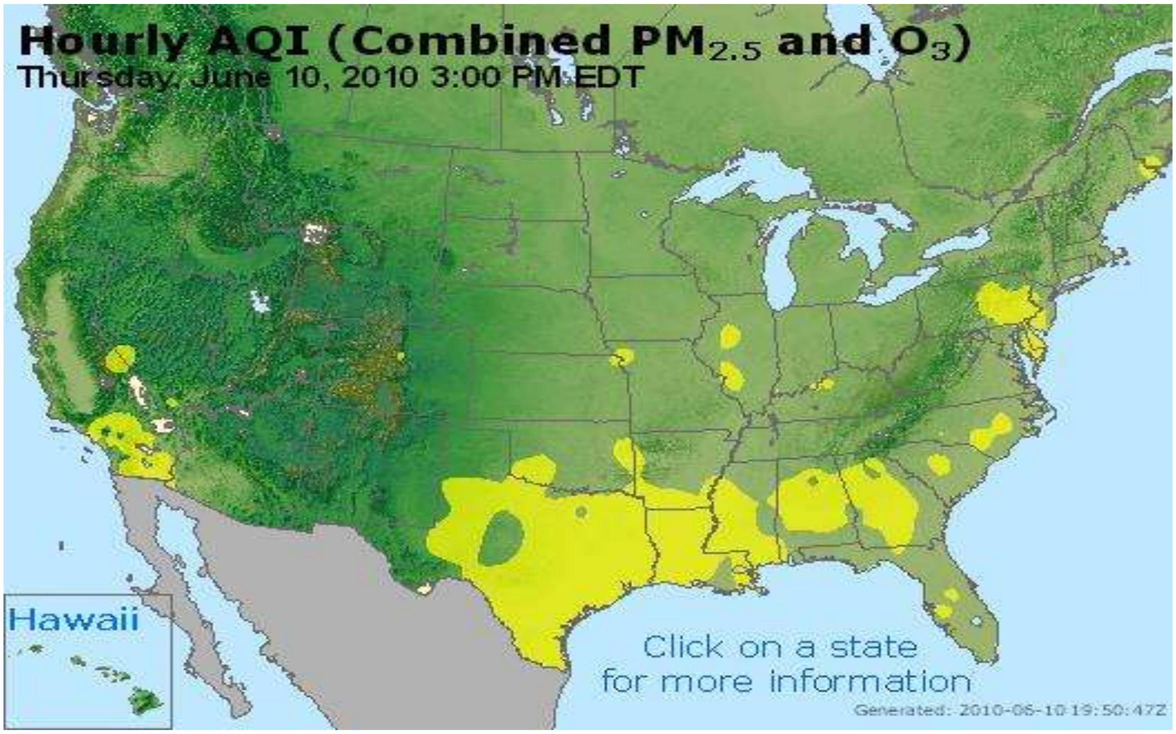
There is no single method of determining the extent or severity of an environmental disaster. Some types of events have severity scales; others do not. This section provides an example of the types of scales and indices that might be used, depending on the type of disaster and how the environment is impacted.

To determine air quality, the US Environmental Protection Agency (EPA) has established the Air Quality Index. This index has established boundaries to indicate the healthfulness of the ambient air in a given location. This information is available through the EPA, and is often is included with local weather forecasts on news programs. Table 6.3.6-1 shows this index. Figure 6.3.6-1 shows how the index is applied for reporting purposes.

Table 6.3.6-1
US Air Quality Index
(Source: EPA)

EPA Air Quality Index		
Air Quality Values	**Levels of Health Concern**	**Color**
0 – 50	**Good**	**Green**
51 – 100	**Moderate**	**Yellow**
101 – 150	**Unhealthy for Sensitive Groups**	**Orange**
151 – 200	**Unhealthy**	**Red**
201 – 300	**Very Unhealthy**	**Purple**
301 – 500	**Hazardous**	**Maroon**

Figure 6.3.6-1
Example of Air Quality Index Reporting
(Source: EPA – www.airnow.gov)



There are many severity scales that are used for chemical or product spills. Each of these scales, however, is specific to the type of chemical or product, and many are specific to the geography of the area.

Depending on the type of environmental disaster that occurred, Galveston could experience severe consequences. Any incident in the Gulf of Mexico or the shipping channels would likely impact Galveston before the Texas mainland. Galveston is also subject to frequent coastal storms, which also increase the likelihood and severity of environmental disasters.

Impact on Life and Property from the Environmental Disaster Hazard

Environmental disasters can have an effect on agriculture, biodiversity, the economy and human health. The causes include pollution, depletion of natural resources, industrial activity or agriculture.

As this Plan was being developed, the world was watching the largest oil contamination event in US history unfold in the Gulf of Mexico. In July 2010, oil from the Deepwater Horizon accident began washing up on the beaches in Galveston and the Bolivar Peninsula to the north of Galveston. Oil has also impacted coastal communities in Louisiana, Alabama, Mississippi and Florida. This incident underscores the point that environmental disasters have far reaching effects and consequences.

As a barrier island, the City has the potential of being impacted by an incident in the Gulf of Mexico. The City has nearly 30 miles of Gulf-facing coastline. The Mineral Management Service, an office of the US Department of the Interior, is responsible for tracking and monitoring offshore drilling in the

Gulf of Mexico. The following table provides the number of leases to drill and the number of active platforms currently drilling petrochemicals in the Gulf of Mexico.

Table 6.3.6-2
Offshore Drilling Statistics
(Source: MMS, DOI)

Offshore Drilling Statistics by Water Depth			
Water Depth (in meters)	**Active Leases**	**Approved Applications for Drilling**	**Active Platforms**
0 – 200	2,320	33,596	3,366
201- 400	147	1,099	21
401 – 800	332	835	9
801 – 1000	419	506	7
1000 and Above	3,492	1,634	25

As depicted above, the majority of drilling occurs in shallower waters. It should be noted that the shelf surrounding Galveston is shallow.

Occurrences of the Environmental Disaster Hazard

In the aftermath of Hurricane Ike, the City experienced an environmental disaster from the damage to privately-owned and maintained septic systems on the West End of Galveston Island. It is unknown exactly how many on-site sewage treatment systems there are on the Island; the Galveston County Health Department (the agency responsible for permitting the systems) estimates there to be several hundred, though many were installed prior to the presently-required permitting process. The small lot sizes, high water tables and regular tidal erosion combine to make this hazard a frequent risk. After Hurricane Ike, entire systems were washed out, leading to bacterial contamination of the property and surrounding area. Also, in many cases, the tank lid collapsed under the additional weight of the water, allowing the contents to escape and the tanks to fill with sand and debris.

The Galveston County Health Department estimates that they identified 140 damaged septic systems after Hurricane Ike, though this number is far from concrete. The wide-spread damage left by Hurricane Ike made it difficult to determine what debris belonged to what property, or even if the septic system was actually damaged. Specific management and cleanup information was provided to homeowners from the Texas Commission on Environmental Quality (TCEQ) and the US Environmental Protection Agency (EPA) to guide property owners through the clean-up and use of these damaged or compromised systems in the wake of Hurricane Ike.

The Galveston area faces the effects of environmental disasters with some regularity; the City is part of the designated Houston-Galveston-Brazoria Ozone Nonattainment Area. Constant challenges are faced in dealing with the effects of poor air quality in the area.

Table 6.3.6-3 provides examples of notable environmental disasters, and provides details of how they impacted the environment and/or the human population. While these incidents did not occur in or impact Galveston, they do illustrate the scenarios that accompany environmental disasters.

Table 6.3.6-3
Historical Examples of Environmental Disasters
(Source: Wikipedia)

Historical Examples of Environmental Disasters			
Type of Incident	**Location**	**Statistics**	**Notes**
Marine Oil Spill	Prince William Sound, Alaska	250,000 barrels (11,000,000 gallons) Oil eventually covered 1,300 miles of coastline and $11,000^2$ miles of ocean	Caused when an oil tanker hit an underwater reef while navigating the shipping channel. Incident is more notable for its devastation of wildlife and natural resources in the area. Wildlife death estimates include • 100,000 – 250,00 birds • 2,800 sea otters • 12 river otters • 300 harbor seals • 247 bald eagles • 22 orcas • Billions of salmon and herring eggs Resulted in the Oil Pollution Act of 1990.
Smog	London, England	4,000 human fatalities in 4 days An additional 8,000 fatalities in following months	Known as "The Great Smog of 1952."
Underground Coal Mine Fire	Centralia, Pennsylvania	400 underground acres of coal mines continue to burn Fire is predicted to extinguish itself in 2250	Underground coal fire began in 1962, continues to burn to the present day. Area became unsafe to inhabit in the late 1970s. Residents were offered government relocation assistance, though some declined and remain to the present day. Entire town was claimed under eminent domain in 1992, and all buildings condemned. US Postal Service revoked the town's zip code in 2002.
Dust Bowl	US Great Plains, including Oklahoma and Texas	2.5 M People displaced 100 M acres affected	The phenomenon was caused by severe drought coupled with decades of extensive farming without crop rotation, fallow fields, cover crops or other techniques to prevent erosion. Deep plowing of the virgin topsoil of the Great Plains had displaced the natural grasses that normally kept the soil in place and trapped moisture even during periods of drought and high winds. During the drought of the 1930s, with no natural anchors to keep the soil in place, it dried, turned to dust, and blew away eastward and southward in large dark clouds. At times the clouds blackened the sky reaching all the way to East Coast cities such as New York and Washington, D.C. Much of the soil ended up deposited in the Atlantic Ocean, carried by prevailing winds which were in part created by the dry and

Historical Examples of Environmental Disasters			
Type of Incident	**Location**	**Statistics**	**Notes**
			bare soil conditions itself. These immense dust storms—given names such as "Black Blizzards" and "Black Rollers"—often reduced visibility to a few feet.

Probability of Future Occurrences of the Environmental Disaster Hazard

While large-scale environmental disasters are rare, smaller occurrences happen regularly on Galveston Island, often as cascading events in conjunction with other hazards. Based on local knowledge and expertise, the HMPSC ranks the probability of future occurrence of the environmental disaster hazard as Moderate.

6.3.7 Extreme Wind

Description of the Extreme Wind Hazard

This section focuses on the extreme wind hazard. This hazard is most often accompanied by other storm hazards, but can occur as a stand-alone hazard event.

As defined by the National Weather Service, wind is

> The horizontal motion of the air past a given point. Winds begin with differences in air pressures. Pressure that's higher at one place than another sets up a force pushing from the high toward the low pressure. The greater the difference in pressures, the stronger the force. The distance between the area of high pressure and the area of low pressure also determines how fast the moving air is accelerated. Meteorologists refer to the force that starts the wind flowing as the "pressure gradient force." High and low pressures are relative. There's no set number that divides high and low pressure. Wind is used to describe the prevailing direction from which the wind is blowing with the speed given usually in miles per hour or knots.

For mitigation planning purposes, extreme winds are most often associated with severe storms, including

- Severe Thunderstorms
- Straight Line Winds
- Tropical Systems/Hurricanes
- Tornadoes

The National Oceanic and Atmospheric Administration (NOAA) defines a severe thunderstorm as

> A thunderstorm that produces a tornado, winds of at least 58 mph (50 knots), and/or hail at least ¾" in diameter. Structural wind damage may imply the occurrence of a severe thunderstorm. A thunderstorm wind equal to or greater than 40 mph (35 knots) and/or hail of at least ½" is defined as approaching severe.

Straight line winds are responsible for most thunderstorm wind damages, and can exceed 100 MPH. One type of straight-line wind, the downburst, is a small area of rapidly descending air beneath a thunderstorm. A downburst can cause damage equivalent to a strong tornado and can be extremely dangerous to aviation

According to NOAA, a hurricane is an intense tropical weather system of strong thunderstorms with well-defined surface circulation and sustained winds of 74 MPH or higher. Hurricanes begin as a tropical disturbance in the open ocean. The following chart illustrates the terms used to define the various tropical weather systems.

Table 6.3.7-1
Tropical Weather System Definitions
(Source: NOAA)

Tropical Weather System Definitions	
Term	**Definition**
Tropical Disturbance	A discrete tropical weather system of apparently organized convection -- generally 100 to 300 NMI in diameter -- originating in the tropics or subtropics, having a

Tropical Weather System Definitions	
Term	**Definition**
	non-frontal migratory character, and maintaining its identity for 24 hours or more. It may or may not be associated with a detectable perturbation of the wind field.
Tropical Cyclone	A warm-core non-frontal synoptic-scale cyclone, originating over tropical or subtropical waters, with organized deep convection and a closed surface wind circulation about a well-defined center. Once formed, a tropical cyclone is maintained by the extraction of heat energy from the ocean at high temperature and heat export at the low temperatures of the upper troposphere. In this they differ from extra-tropical cyclones, which derive their energy from horizontal temperature contrasts in the atmosphere.
Tropical Depression	A tropical cyclone in which the maximum sustained surface wind speed (using the U.S. 1-minute average) is 33 KT (38 MPH or 62 KM/HR) or less.
Tropical Storm	A tropical cyclone in which the maximum sustained surface wind speed (using the U.S. 1-minute average) ranges from 34 KT (39 MPH or 63 KM/HR) to 63 KT (73 MPH or 118 KM/HR).
Hurricane	A tropical cyclone in which the maximum sustained surface wind (using the U.S. 1-minute average) is 64 KT (74 MPH or 119 KM/HR) or more. The term hurricane is used for Northern Hemisphere tropical cyclones east of the International Dateline to the Greenwich Meridian. The term typhoon is used for Pacific tropical cyclones north of the Equator west of the International Dateline.

The ingredients for a hurricane include a pre-existing weather disturbance, warm tropical waters, moisture and relatively light winds aloft. Persistent, favorable conditions can produce violent winds, destructive waves, torrential rains and powerful floods. Annually, an average of ten (10) tropical systems develop over the Atlantic Ocean, Caribbean Sea, and Gulf of Mexico. Many of these storms remain over open water and never move towards land. In an average year, six (6) of these storms become hurricanes. In an average three year period, five (5) hurricanes will strike the US coastline, anywhere from Texas to Maine. Of these, two (2) are typically major or intense hurricanes, with classifications of Category 3 or higher.

A hazard associated with hurricanes is extreme wind. As wind speeds increase, pressure against objects is added at a disproportionate rate. Pressure against a wall rises with the square of the wind speed, which means that a threefold increase in wind speed gives a nine-fold increase in pressure. Thus, a 25 MPH wind causes approximately 1.6 pounds of pressure per foot^2. A 4”x8” sheet of plywood will be pushed by a weight of 50 pounds. In 75 MPH winds, that force becomes 450 pounds, and in 125 MPH winds, it becomes 1,250 pounds. For some structures, this force is enough to cause failure. These winds will weaken after landfall due to loss of warm-water energy source, and the encountering of great friction over land.

Tornadoes are also extreme wind events. The most destructive of all atmospheric phenomena, tornadoes are violently rotating columns of air. These columns extend between and in contact with a cloud and the Earth’s surface. The most violent tornadoes have rotational wind speeds of 250 MPH; in extreme cases, rotational wind speeds may approach 300 MPH. Tornadoes are often produced by severe thunderstorms and hurricanes as they move ashore.

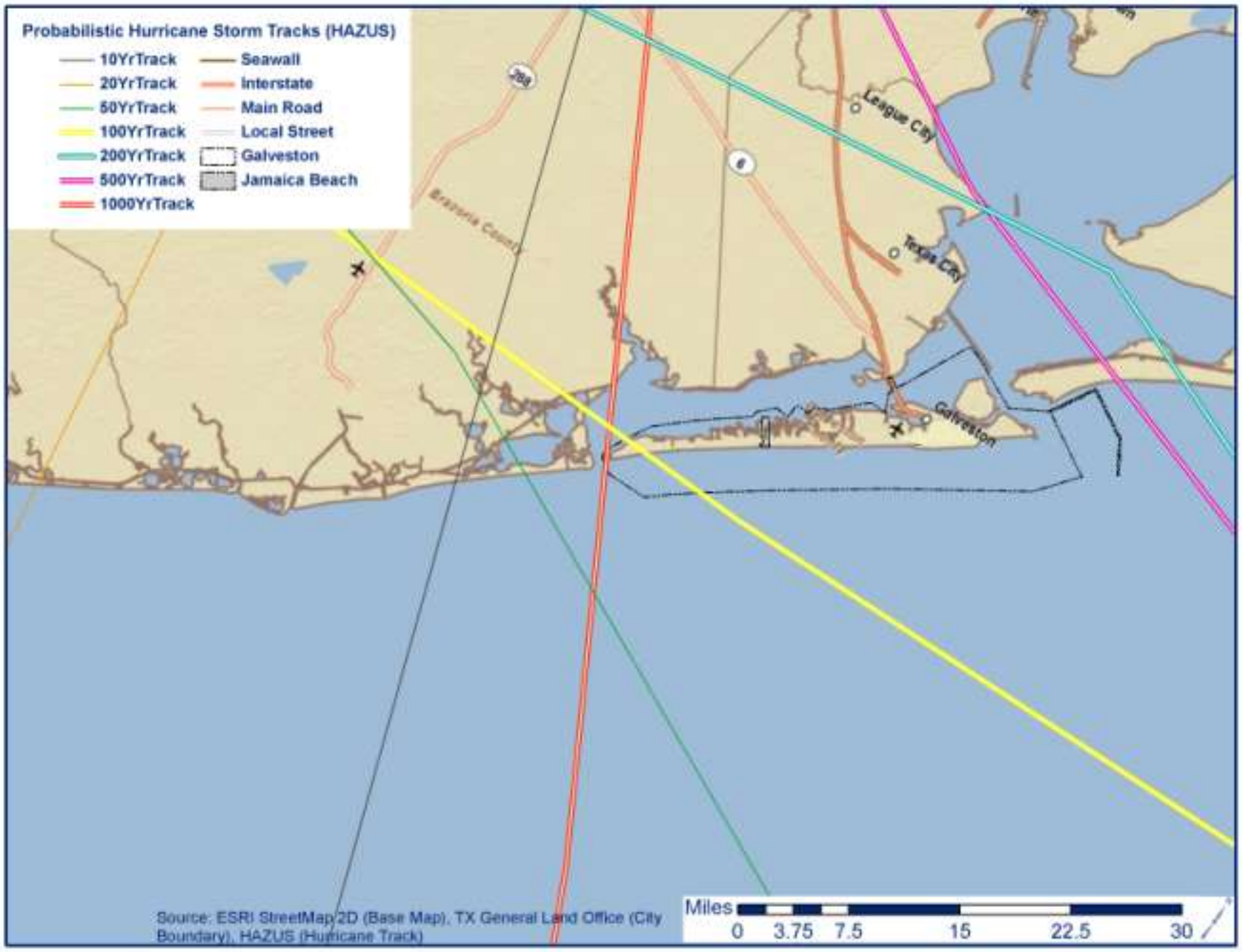
Location of the Extreme Wind Hazard

Extreme winds can and do impact the entirety of the city of Galveston. As the City is a barrier island that is approximately 2 miles wide and 30 miles long, all areas of the City are equally exposed to and at risk from extreme wind events.

Map 6.3.7-1 shows the locations of historic tornado touchdowns in Galveston since 1961. Map 6.3.7-2 shows the probable path of hurricanes affecting Galveston, based on historic occurrences and averages.

Map 6.3.7-1
Historic Tornado Touchdowns in Galveston
(Source: ESRI, NCDC)

Map 6.3.7-2
Probabilistic Hurricane Storm Tracks in Galveston
(Source: ESRI, GLO, HAZUS)



Severity of the Extreme Wind Hazard

The severity and extent of extreme winds events will vary, depending on the type of storm that produces the event. Table 6.3.7-2 demonstrates the Beaufort Wind Force Scale, used to describe primarily maritime wind conditions.

Table 6.3.7-2
Beaufort Wind Force Scale
(Source: Mount Washington Observatory)

Beaufort Wind Force Scale			
Beaufort Number	**Wind Speed in MPH**	**Seaman's Term**	**Effects on Land**
0	> 1	Calm	Calm; smoke rises vertically
1	1-3	Light Air	Smoke drift indicates wind direction; vanes do not move
2	4-7	Light Breeze	Wind felt on face; leaves rustle; vanes begin to move

Beaufort Wind Force Scale			
Beaufort Number	Wind Speed in MPH	Seaman's Term	Effects on Land
3	8-12	Gentle Breeze	Leaves, small twigs in constant motion; light flags extended
4	13-18	Moderate Breeze	Dust, leaves and loose paper raised up; small branches move
5	19-24	Fresh Breeze	Small trees begin to sway
6	25-31	Strong Breeze	Large branches of trees in motion; whistling heard in wires
7	32-28	Moderate Gale	Whole trees in motion; resistance felt in walking against the wind
8	39-46	Fresh Gale	Twigs and small branches broken off trees
9	47-54	Strong Gale	Slight structural damage occurs; slate blown from roofs
10	55-63	Whole Gale	Seldom experienced on land; trees broken; structural damage occurs
11	64-72	Storm	Very rarely experienced on land; usually with widespread damage
12	73<	Hurricane Force	Violence and destruction

Hurricanes are categorized according to the strength of their winds using the Saffir-Simpson Wind Scale. This scale ranks only wind speed, and increases in scale. It is important to note that lower category storms can inflict greater damage than higher category storms, depending on where they strike, other weather they interact with, and how slow their forward speed. A prime example is Hurricane Ike. This storm had winds classified as Category 2, yet was one of the costliest and most destructive hurricanes in US history.

Table 6.3.7-3 illustrates the wind speed classification and expected wind effects on land from various coastal storm categories, as provided by the National Hurricane Center. These descriptions of land effects are general and are for explanatory purposes only. The actual damage to land from a given storm will be reliant on a variety of factors, including construction, placement, age, and condition of the structure.

Table 6.3.7-3
Saffir-Simpson Wind Scale
(Source: NHC)

Saffir-Simpson Wind Scale			
Category	Expected Wind Speed (mph)	Example Storm(s)	Effects on Land
Category 1 Hurricane	74 – 95	Hurricane Dolly (2008) is an example of a hurricane that brought Category 1 winds and impacts to South Padre Island, Texas.	Older (mainly pre-1994 construction) mobile homes could be destroyed, especially if they are not anchored properly as they tend to shift or roll off their foundations. Newer mobile homes that are anchored properly can sustain damage involving the removal of shingle or metal roof coverings, and loss of vinyl siding. Some poorly constructed frame homes can experience major damage, involving loss of the roof covering and damage to gable ends as well as the removal of porch coverings and awnings. Unprotected windows may break if struck by flying debris. Falling and broken glass will pose a significant danger even after the

Saffir-Simpson Wind Scale			
Category	**Expected Wind Speed (mph)**	**Example Storm(s)**	**Effects on Land**
			storm. Large branches of trees will snap and shallow rooted trees can be toppled. Extensive damage to power lines and poles will likely result in power outages that could last a few to several days.
Category 2 Hurricane	96 – 110	Hurricane Frances (2004) is an example of a hurricane that brought Category 2 winds and impacts to coastal portions of Port St. Lucie, Florida with Category 1 conditions experienced elsewhere in the city.	There is a substantial risk of injury or death to people, livestock, and pets due to flying and falling debris. Older (mainly pre-1994 construction) mobile homes have a very high chance of being destroyed and the flying debris generated can shred nearby mobile homes. Newer mobile homes can also be destroyed. Poorly constructed frame homes have a high chance of having their roof structures removed especially if they are not anchored properly. Unprotected windows will have a high probability of being broken by flying debris. Well-constructed frame homes could sustain major roof and siding damage.
Category 3 Hurricane	111 – 130	Hurricane Ivan (2004) is an example of a hurricane that brought Category 3 winds and impacts to coastal portions of Gulf Shores, Alabama with Category 2 conditions experienced elsewhere in the city.	There is a high risk of injury or death to people, livestock, and pets due to flying and falling debris. Nearly all older (pre-1994) mobile homes will be destroyed. Most newer mobile homes will sustain severe damage with potential for complete roof failure and wall collapse. Poorly constructed frame homes can be destroyed by the removal of the roof and exterior walls. Unprotected windows will be broken by flying debris. Well-built frame homes can experience major damage involving the removal of roof decking and gable ends. There will be a high percentage of roof covering and siding damage to apartment buildings and industrial buildings. Isolated structural damage to wood or steel framing can occur. Many trees will be snapped or uprooted, blocking numerous roads. Electricity and water will be unavailable for several days to a few weeks after the storm passes.
Category 4 Hurricane	131 – 155	Hurricane Charley (2004) is an example of a hurricane that brought Category 4 winds and impacts to coastal portions of Punta Gorda, Florida with Category 3 conditions experienced elsewhere in the city.	There is a very high risk of injury or death to people, livestock, and pets due to flying and falling debris. Nearly all older (pre-1994) mobile homes will be destroyed. A high percentage of newer mobile homes also will be destroyed. Poorly constructed homes can sustain complete collapse of all walls as well as the loss of the roof structure. Well-built homes also can sustain severe damage with loss of most of the roof structure and/or some exterior walls. Extensive damage to roof coverings, windows, and doors will occur. Large amounts of windborne debris will be lofted into the air. Windborne debris damage will break most unprotected windows and penetrate some protected windows. There will be a high percentage of structural damage to the top floors of apartment buildings. Fallen trees and power poles will isolate residential areas. Power outages will last for weeks to possibly months.
Category 5 Hurricane	>156	Hurricane Andrew (1992) is an example of a hurricane that brought Category 5 winds and impacts to coastal portions of Cutler Ridge, Florida with Category 4 conditions experienced	People, livestock, and pets are at very high risk of injury or death from flying or falling debris, even if indoors in mobile homes or framed homes. Almost complete destruction of all mobile homes will occur, regardless of age or construction. A high percentage of frame homes will be destroyed, with total roof failure and wall collapse. Extensive damage to roof covers, windows, and doors will occur. Complete collapse of many older metal buildings can occur. Most unreinforced masonry walls will fail which

Saffir-Simpson Wind Scale			
Category	**Expected Wind Speed (mph)**	**Example Storm(s)**	**Effects on Land**
		elsewhere in south Miami-Dade County.	can lead to the collapse of the buildings. Fallen trees and power poles will isolate residential areas. Power outages will last for weeks to possibly months. Long-term water shortages will increase human suffering.

The Saffir-Simpson Wind Scale does not address the potential for other hurricane-related impacts, such as storm surge, rainfall-induced floods, and tornadoes. It should also be noted that these wind-caused damage general descriptions are to some degree dependent upon the local building codes in effect and how well and how long they have been enforced. For example, building codes enacted during the 2000s in Florida, North Carolina and South Carolina are likely to reduce the damage to newer structures from that described in Table 6.3.7-3. However, for a long time to come, a significant portion of the building stock in existence on the coast will not have been built to higher code. This is especially true for historic structures. Hurricane wind damage is also very dependent upon other factors, such as duration of high winds, change of wind direction, and age of structures.

Tornado wind forces are measured and described according to the Fujita Scale. The Fujita Scale is largely a residential structure damage scale, which tends to much more standardized construction than commercial structures. The Fujita Scale is intended to describe the expected damage to well-built residential structures. This makes its use often misleading, as poorly built structures can suffer significant structural damage under lesser winds than the Scale would suggest. The Storm Prediction Center, a NOAA office, states the following regarding the use of the Fujita Scale:

> Do not use F-scale winds literally. These precise wind speed numbers are actually guesses and have never been scientifically verified. Different wind speeds may cause similar-looking damage from place to place -- even from building to building. *Without a thorough engineering analysis of tornado damage in any event, the actual wind speeds needed to cause that damage are unknown.*

Table 6.3.7-4 illustrates the Fujita Scale in use prior to February 2007.

Table 6.3.7-4
Fujita Tornado Scale (Pre-February 2007)
(Source: Storm Prediction Center)

Fujita Scale			
F-Scale Number	**Intensity Phrase**	**Wind Speed**	**Type of Damage**
F0	Gale tornado	40-72 mph	Some damage to chimneys; breaks branches off trees; pushes over shallow-rooted trees; damages sign boards.
F1	Moderate tornado	73-112 mph	The lower limit is the beginning of hurricane wind speed; peels surface off roofs; mobile homes pushed off foundations or overturned; moving autos pushed off the roads; attached garages may be destroyed.
F2	Significant tornado	113-157 mph	Considerable damage. Roofs torn off frame houses; mobile homes demolished; boxcars pushed over; large trees snapped or uprooted; light object missiles generated.
F3	Severe tornado	158-206 mph	Roof and some walls torn off well constructed houses; trains overturned; most trees in forest uprooted

Fujita Scale			
F-Scale Number	**Intensity Phrase**	**Wind Speed**	**Type of Damage**
F4	Devastating tornado	207-260 mph	Well-constructed houses leveled; structures with weak foundations blown off some distance; cars thrown and large missiles generated.
F5	Incredible tornado	261-318 mph	Strong frame houses lifted off foundations and carried considerable distances to disintegrate; automobile sized missiles fly through the air in excess of 100 meters; trees debarked; steel reinforced concrete structures badly damaged.
F6	Inconceivable tornado	319-379 mph	These winds are very unlikely. The small area of damage they might produce would probably not be recognizable along with the mess produced by F4 and F5 wind that would surround the F6 winds. Missiles, such as cars and refrigerators would do serious secondary damage that could not be directly identified as F6 damage. If this level is ever achieved, evidence for it might only be found in some manner of ground swirl pattern, for it may never be identifiable through engineering studies

In February 2007, use of the Fujita Scale was discontinued. In its place, the Enhanced Fujita Scale was put into use. The Enhanced Fujita Scale retains the same basic design as its predecessor, but reflects a more refined assessment of tornado damage surveys, standardization and damage consideration to a wider range of structure types. The new scale takes into account how most structures are designed, and is thought to be a much more accurate representation of the surface wind speeds in the most violent tornadoes. It is important to note the date a tornado occurred, as tornadoes which occurred prior to February 2007 are classified by the old scale and will not be converted to the Enhanced Fujita Scale.

Table 6.3.7-5 illustrates the Enhanced Fujita Scale, currently in use.

Table 6.3.7-5
Enhanced Fujita Tornado Scale (Post-February 2007)
(Source: Storm Prediction Center)

Enhanced Fujita (EF) Scale		
Enhanced Fujita Category	**Wind Speed (mph)**	**Potential Damage**
EF0	65-85	**Light damage.** Peels surface off some roofs; some damage to gutters or siding; branches broken off trees; shallow-rooted trees pushed over.
EF1	86-110	**Moderate damage.** Roofs severely stripped; mobile homes overturned or badly damaged; loss of exterior doors; windows and other glass broken.
EF2	111-135	**Considerable damage.** Roofs torn off well-constructed houses; foundations of frame homes shifted; mobile homes completely destroyed; large trees snapped or uprooted; light-object missiles generated; cars lifted off ground.
EF3	136-165	**Severe damage.** Entire stories of well-constructed houses destroyed; severe damage to large buildings such as shopping malls; trains overturned; trees debarked; heavy cars lifted off the ground and thrown; structures with weak foundations blown away some distance.

Enhanced Fujita (EF) Scale		
Enhanced Fujita Category	**Wind Speed (mph)**	**Potential Damage**
EF4	166-200	**Devastating damage.** Well-constructed houses and whole frame houses completely leveled; cars thrown and small missiles generated.
EF5	>200	**Incredible damage.** Strong frame houses leveled off foundations and swept away; automobile-sized missiles fly through the air in excess of 100 m (109 yd); high-rise buildings have significant structural deformation; incredible phenomena will occur.

As a barrier island, Galveston can expect to experience the entire range of extreme winds, including extreme tornadoes. Though extreme winds from hurricanes and other coastal storms are a more probable threat, extreme winds from tornadoes are not outside the realm of possibility for Galveston.

Impact on Life and Property from the Extreme Wind Hazard

Extreme winds have the potential to devastate the City of Galveston. The City's location as a barrier island makes it particularly susceptible to extreme winds. All areas of the City are at risk from the extreme wind hazard. Though the City had adopted and enforces stringent building codes, designed to protect the built environment, these building codes only apply to newer construction. Old building stock remains at risk from extreme wind events.

Hurricane Carla, which made landfall on the Texas Coast in 1961, perfectly represents the impact of extreme winds on life and property. Carla attained Category 5 conditions, but weakened to a Category 4 hurricane shortly before landfall, between Port O'Connor and Port Lavaca, Texas. Carla was responsible for 43 deaths and more than $2 billion in damages (more than $14B in 2009 dollars).

Because of its large size, the entire Texas coast was affected, and damage was reported as far inland as Dallas. Sustained winds were reported to be 115 mph in Matagorda, 110 mph in Victoria and 88 mph in Galveston. Wind gusts as high as 170 mph were recorded at Port Lavaca. Much of the damage was done well away from the landfall site, as Carla spawned one of the largest hurricane-related tornado outbreaks on record at the time, when 26 tornadoes touched down within its circulation. One F4 tornado ripped through downtown Galveston, killing several (sources differ on the exact number, varying from 6 to 12). Outside the protection of the Galveston Seawall, structures on the island were severely damaged by storm surge.

In 1983, Hurricane Alicia struck the Island, making landfall as a Category 3 hurricane. 23 tornadoes were reported in association with Alicia; 14 of those were located in the Galveston and Houston-Hobby Airport area. The City of Houston suffered billions of dollars in damage. Thousands of glass panes in downtown skyscrapers were shattered by gravel blown off rooftops. Although Alicia was a small Category 3 hurricane, a total of 2,297 structures were destroyed by Alicia, with another 3,000 experiencing major damage. More than 10,000 structures had minor damage. Houston Lighting and Power reported that about 750,000 residential structures were without electricity after Alicia's landfall. Many stores had to stay closed for days afterward due to risks of falling glass in the area.

In Galveston, the western beach had its public beach boundary shifted landward approximately 150 feet. Approximately 5 feet of sand was scoured, leaving beachfront homes in a natural vegetation state. This moved many beachfront homes onto public beach, and the Texas Attorney General's office declared that they were in violation of the Texas Open Beaches Act and forbade the repair or rebuilding of those homes. The US Army Corps of Engineers stated that if the Galveston Seawall had not been in existence, another $100 million in damage could have occurred.

Occurrences of the Extreme Wind Hazard

Table 6.3.7-6 details selected occurrences of extreme wind events in the City of Galveston. The storm type and estimated damages, fatalities and injuries are noted (where data available). Note that this table is intended to be representative of the hazard occurrences, and does not include all known occurrences.

Table 6.3.7-6
Occurrences of the Extreme Wind Hazard in the City of Galveston
(Source: Galveston County Plan Update, NCDC, NHC, *Galveston: A History* (David McComb, 1986))

Occurrences of the Extreme Wind Hazard in the City of Galveston					
Date	**Type of Extreme Winds**	**Fatalities**	**Injuries**	**Estimated Damages**	**Notes**
1854	Hurricane	4	Unknown	$466,950	105 MPH winds associated with Category 2 hurricane. Many ships capsized and 2 steamers sank
1891	Hurricane	Unknown	Unknown	Unknown	90 MPH winds recorded.
September 8, 1900	The Great Hurricane	8,000	Unknown	$99.4B (in 2005 dollars)	Estimated winds of 135 MPH (217 HM/H) at landfall, making it a Category 4 storm on the Saffir-Simpson Hurricane Scale. The highest measured wind speed was 100 miles per hour (160 km/h) just after 6 p.m., but the Weather Bureau's anemometer was blown off the building shortly after that measurement was recorded. Maximum winds were estimated at 120 MPH (190 KM/H) at the time, though later estimates placed the hurricane at the higher Category 4 classification. While the sheer amount of death and destruction is due largely to the storm surge that overtopped the island (an estimated 15 feet, compared to the average natural elevation of 8.7 feet at the time), the winds associated with the storm made such a storm surge possible.
August 17, 1915	Hurricane	8-11 (low number attributed to newly-built Seawall)	Unknown	$61M+	135 MPH winds led to 5-6 feet of flooding in downtown Galveston. Tides were 9-14 feet above normal, and surge was estimated at more than 15 feet. 300 feet of beach washed away, along with the earthen approaches to the Causeway. City's water main was severed, and every ship in the harbor was damaged.
1932	Hurricane	Unknown	Unknown	Unknown	All electrical and phone service was cut to the island. 1 foot of rain fell. Extensive wind damage. Category 4 at landfall
July 27, 1943	Hurricane	19	33	$214M+	Recorded as a Category 1 storm with 70-90 MPH Winds. Storm produced tornadoes that damaged downtown and The Strand. Much of the forecast and damage information was suppressed by the War Department – US Weather Bureau destroyed the official readings and recordings and could not issue advisories with forecast information
July 25, 1959	Hurricane Debra	Unknown	Unknown	Unknown	100 MPH winds recorded
September 11, 1961	Hurricane Carla	6	Unknown	$127M+	88 MPH Winds. 4 tornado touchdowns; 1 tornado was an F-4. 120 buildings destroyed by tornadoes.
June 10, 1975	Severe Thunder-storm	0	0	None Reported	61 KTS
August 31, 1981	Severe Thunder-storm	0	0	None Reported	80 KTS
September 1981	Tornadoes	Unknown	Unknown	$7M+	Seven (7) tornadoes recorded throughout month.

Occurrences of the Extreme Wind Hazard in the City of Galveston					
Date	**Type of Extreme Winds**	**Fatalities**	**Injuries**	**Estimated Damages**	**Notes**
1983	Hurricane Alicia	0	Unknown	$639M+	Eye crossed the western end of the San Luis Pass, putting the majority of the island on the eastern side of the storm. 96-102 MPH sustained winds produced 12 foot tides. 7 ¾ inches of rain in Galveston. 14 tornadoes reported between Galveston Island and Hobby Airport. 50-200 feet of beach washed away, leaving many private residences on now-public beaches
May 2, 1993	Severe Thunder-storm	0	0	$50M (County-wide)	Numerous trees were knocked down, roofs were damaged, and power line were blown or knocked down county-wide. The National Weather Service Office in downtown Galveston reported a wind gust to 68 MPH while at Scholes Field a peak gust of 98 MPH was recorded. At Scholes Field three hangers were destroyed and two private aircraft were damaged. Two shrimp boats were blown onto the north jetty at the entrance to Galveston Bay. One shrimp boat capsized in the West Bay. The United States Coast Guard reported numerous fishing boats and barges broke away from their mooring. Galveston City Manager reported 64 businesses damaged; twelve apartment complexes and several large stores had roofs stripped of shingles and windows blown in. Near 10,000 homes were without power. Many vehicles were damaged from flying debris.
March 9, 1994	Severe Thunder-storm	0	0	$5,000	Bow echo moved across western portion of Galveston Island producing winds of 80 to 100 MPH. These winds were recorded by three citizens who owned home-based anemometers. The highest wind recorded was 102 MPH. Damage was minimal since most homes in this region were on stilts in this region. Only damage was some breakaway walls on the ground floor were blown down.
June 23, 1996	Severe Thunder-storm	0	0	None Reported	Coast Guard reported 50-70 KT gusts at Pelican Cut in Galveston Bay.
November 5, 1997	Severe Thunder-storm	0	0	$51,000	Power lines down and an 18 -wheeler overturned at Harborside Drive & Avenue A. Windows blown out at the Moody Center on the Seawall. Garden shed at nursery on 32nd Street destroyed. Power lines blown down in eastern Galveston. Hotel roof on 61st Street blown off.
June 6, 1998	Severe Thunder-storm	0	0	$20,000	Coast Guard estimated 85 KT winds at the ferry landing. 150 foot dry dock blew off moorings into a ship. Dredge pipes (75 foot long, 2000-3000 pounds) blown off shore into the water.
September 7-12, 1998	Tropical Storm Frances	3	0	$287.2M (over entire affected area, mostly due to flooding)	Winds ranged from 25 to 35 KT (29 - 40 MPH) for over 24 hours starting around midnight on the September 10 and continuing until the early morning of September 11. The strongest wind recorded was 47 KT (54 MPH) at Galveston Scholes Field around 6pm on Sept. 10. Major impact and resultant damage occurred in Galveston, Harris, Brazoria and Matagorda counties of Texas. All four of these counties received a Presidential Disaster Declaration to help in the relief and recovery efforts. In these four counties total damage exceeded $286 million dollars. Most of this damage was along the coast and around Galveston Bay where high tides and winds destroyed dunes and personal property.
October 6, 1998	Severe Thunder-storm	0	0	$5,000	75 MPH gusts at the Ferry landing in Galveston

Occurrences of the Extreme Wind Hazard in the City of Galveston					
Date	**Type of Extreme Winds**	**Fatalities**	**Injuries**	**Estimated Damages**	**Notes**
May 10, 1999	Severe Thunder-storm	0	0	$200,000	Portion of convenience store on Broadway destroyed. Fence blown down at Gulf Health Care Center. Numerous power poles, street signs and traffic signs blown down between 61st and 71st Streets near Harborside Drive. Roof of home torn off and 2-ton boat blown into car along Channelview Drive. Numerous reports of trees and power lines down across island. Wind speed not recorded.
May 2, 2000	Severe Thunder-storm	0	0	$1M	A strong storm system produced widespread severe thunderstorms over southeast Texas. Storm surveys revealed most of the wind damage to be due to downburst winds. Severe damage occurred at Scholes Field in Galveston where several small planes were overturned and the NOAA P-3 research aircraft was damaged.
April 8, 2002	Severe Thunder-storm	0	0	$70,000	There were an extensive number of power lines down along FM 3005 on Galveston Island. Wind damage to homes on the West End of Galveston Island, most extensive at Terramar and Bay Harbor subdivisions, with 4 houses missing up to half their roofs, and a couple dozen homes with missing shingles and blown out windows.
December 30, 2002	Severe Thunder-storm	0	0	$30,000	140 feet of roof ripped off the Shops at the Balinese Room on the Galveston seawall. Exactly one week after the December 23rd outbreak, Southeast Texas received another round of severe weather as the next storm system moved out of the southwestern U.S. toward Texas. This event only lasted three hours (compared to eighteen hours on the 23rd). This event only had three tornadoes (compared to ten on the 23rd). However, damage from two of these three tornadoes was significant due to the fact that it occurred over heavily populated areas. This event had no injuries, and the total damage cost was just under $450,000. Wind reported at 65 KTs at the Pleasure Pier.
July 14, 2003	Hurricane Claudette	0	2	$10.9M (over entire affected area, mostly due to flooding)	Historical records dating back to 1851 indicate Claudette is the first July hurricane to make landfall in this area. Large geo-tubes on Galveston Island and the Bolivar Peninsula did significantly reduce erosion. Coastal roads along the west end of Galveston Bay were under water due to tidal flooding. The highest reported wind gust was at the South Texas Nuclear Power Plant in Matagorda County where an 86 MPH wind gust was recorded at 1000 CDT on July 15th. The highest recorded sustained wind (58 MPH) was recorded at East Matagorda Bay in Matagorda County.
May 08, 2005	Severe Thunder-storm	0	0	$175,000	Building damage along the Port of Galveston, vehicle blown off the road and trees down. One house shifted about ten feet into another house next door, dislodging it from its piers (both homes were Galveston 1900 Storm survivors). Wind speeds measured at 61 KTs.

Occurrences of the Extreme Wind Hazard in the City of Galveston					
Date	**Type of Extreme Winds**	**Fatalities**	**Injuries**	**Estimated Damages**	**Notes**
September 23, 2005	Hurricane Rita	3 direct; 49 indirect	3	$159.9 M (over entire affected area) $60,000 specific to City of Galveston; unknown private losses	Rita was a Category 3 hurricane at landfall. Widespread damage consisting of downed trees and power lines occurred generally along and east of a line from Crystal Beach to Liberty to Livingston to Lufkin in Texas. Dunes protecting many beach houses along the west end of Galveston Island were washed away. Large geo-tubes along portions of the West End of Galveston Island did reduce erosion in areas where they were installed. Most flooding was due to high tides along Galveston Island and the Bolivar Peninsula. Most of this flooding actually occurred near the time of landfall as water in Galveston Bay was pushed south out of the Bay onto the north facing shores of the island and the peninsula. Tides remained high on Saturday (after Rita made landfall) as strong westerly winds pushed water into East Bay. In Galveston County, tropical storm force sustained winds with gusts to hurricane force were reported across the county, especially on the Bolivar Peninsula. Numerous power poles and road signs were blown down on Bolivar. Many of the beach homes received roof damage. Numerous trees were down with small structure damage on High Island. Power was out to most of the county on Saturday. In Galveston's historic district, a large brick-covered side of a three-story building collapsed and three other buildings caught fire and were destroyed during the height of the storm. There were three directly related injuries. Small structure, dock, and pier damage along with downed power lines occurred across Galveston Island. Total damage across the county was around $15 million. No tornadoes were reported with Rita.
May 22, 2007	Severe Thunder-storm	0	0	None Reported	53 KTs winds reported. Tree downed in the Gulf Village subdivision near Stewart Road.
September 12, 2007	Hurricane Humberto	0	0	$2.5M (0ver the affected area)	The majority of the damage from Humberto was due to high winds and fresh water flooding that caused minor structural damage along with knocking down trees and power lines.
September 13, 2008	Hurricane Ike	Not Yet Finalized	Not Yet Finalized	Not Yet Finalized	When Hurricane Ike made landfall at Galveston Island, its winds were sustained at 95 KTS or 109 MPH. At the time of landfall, aircraft dropsondes and land-based Doppler radar measured wind speeds approximately 91 M (300 feet) above the surface at 115 KTS or 130 MPH. These strong winds caused major damage to the high rise buildings in the downtown Houston area as well as some of the oil refineries in Texas City.
August 30, 2009	Severe Thunder-storm, Tornado	0	0	Unknown	51 KTs Wind gust was measured at Galveston Scholes Field. Several strong thunderstorms formed late in the evening near Galveston Island along a nearly stationary surface front. A waterspout developed off the coast near Galveston Island before moving inland and doing damage as a tornado.

Probability of Future Occurrences of the Extreme Wind Hazard

Table 6.3.7-7 shows the average hurricane wind speed return interval in the City of Galveston.

Table 6.3.7-7
Average Hurricane Wind Speed Return Interval
(Source: Galveston County Plan Update, HAZUS-MH)

Average Hurricane Wind Speed Return Interval						
10 Year	**20 Year**	**50 Year**	**100 Year**	**200 Year**	**500 Year**	**1000 Year**
69 MPH	89 MPH	112 MPH	124 MPH	134 MPH	145 MPH	153 MPH

Based on the return interval of hurricane-force winds, the history of extreme wind events, local knowledge, and the City's location as a barrier island, the probability of a future occurrence of extreme winds can be rated as High.

6.3.8 Flooding

Description of the Flooding Hazard

Floods are naturally occurring events. Excess water from snowmelt, rainfall, or storm surge accumulates and either overflows onto banks or backs up into adjacent floodplains. Flooding in coastal environments can be exacerbated by tidal influence in low lying areas.

The National Flood Insurance Program (NFIP) defines flood in the following way:

> A general and temporary condition of partial or complete inundation of two or more acres of normally dry land area or of two or more properties from overflow of inland or tidal waters, from unusual and rapid accumulation or runoff of surface waters from any source, or from mudflow.

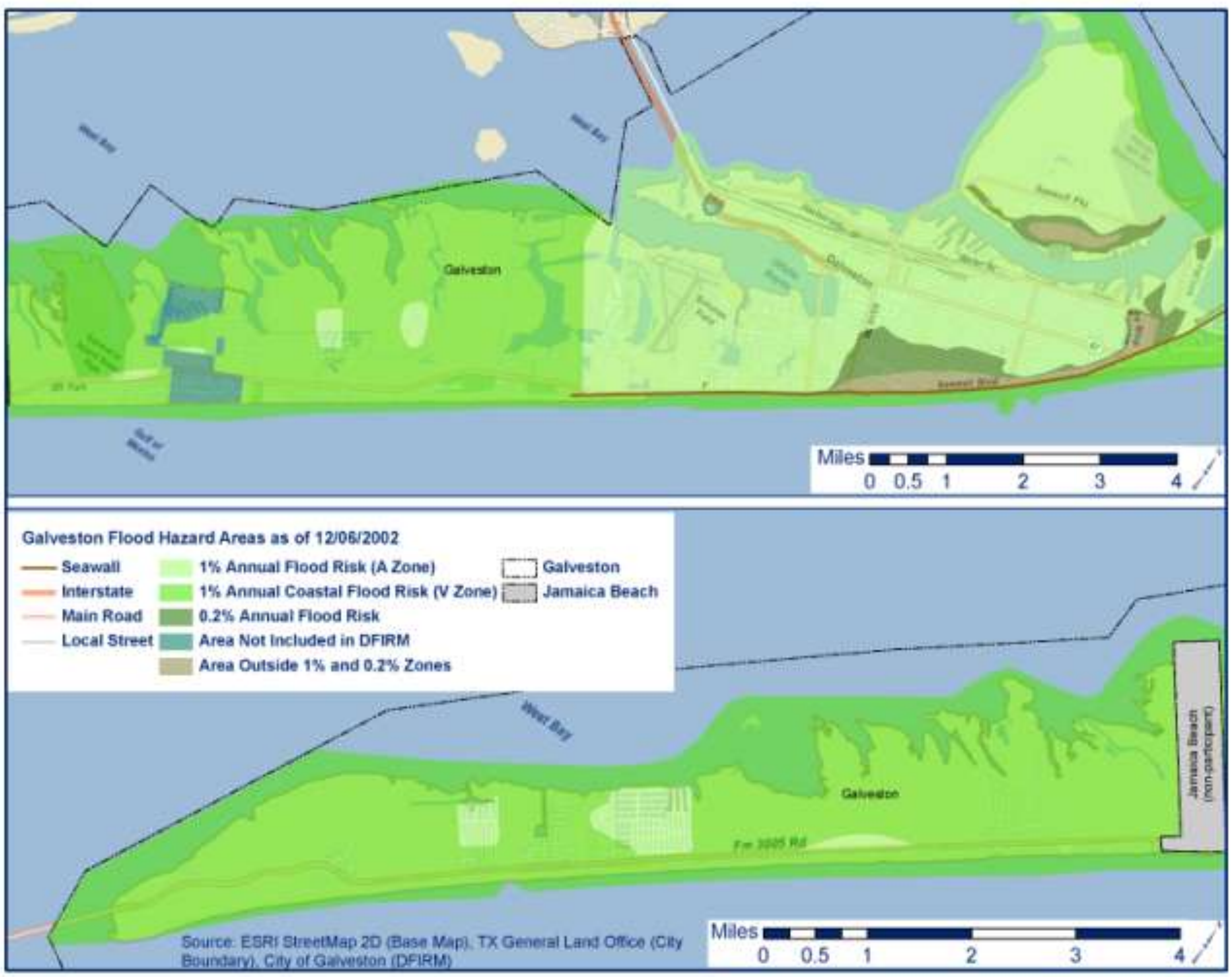
In support of the NFIP, FEMA identifies those areas that are more vulnerable to flooding by producing Flood Hazard Boundary Maps (FHBM), Flood Insurance Rate Maps (FIRM), and Flood Boundary and Floodway Maps (FBFM). Several areas of flood hazards are commonly identified on these maps. One of the areas identified in the Special Flood Hazard Area (SFHA), which is a high-risk area defined as any land that would be inundated by a flood having a 1% chance of occurring in any given year (also known as the base flood). The flood zone designations are defined as follows:

- **Zone V (1% annual chance flooding).** Areas along coasts subject to inundation by the 1% annual chance of flooding with additional hazards associated with storm-induced waves. Because hydraulic analyses have not been performed, no BFEs or flood depths are shown.
- **Zones VE and V1-30 (1% annual chance flooding).** Areas along coasts subject to inundation by the 1% annual chance of flooding with additional hazards associated with storm-induced waves. BFEs derived from detailed hydraulic analyses are shown within these zones. (Zone VE is used on new and revised maps in place on Zones V1-30.)
- **Zone A (1% annual chance flooding).** Areas with a 1% annual chance of flooding and a 26% chance of flooding over the life of a 30-year mortgage. Because detailed analyses are not performed for such areas, no depths or base flood elevations are shown within these areas.
- **Zone AE (1% annual chance of flooding).** Areas with a 1% annual chance of flooding and a 26% chance of flooding over the life of a 30-year mortgage. In most instances, base flood elevations derived from detailed analyses are shown at selected intervals within these zones.
- **Zone AH (1% annual chance of flooding).** Areas with a 1% annual chance of flooding where shallow flooding (usually areas of ponding) can occur with average depths between one and three feet.
- **Zone AO (1% annual chance of flooding).** Areas with a 1% annual chance of flooding, where shallow flooding average depths are between one and three feet.
- **Zone X (shaded) (0.2% annual chance of flooding).** Represents areas between the limits of the 1% annual chance flooding and 0.2% chance flooding.
- **Zone X (unshaded).** Areas outside of the 1% annual chance floodplain and 0.2% annual chance floodplain, areas of 1% annual chance sheet flow flooding where average depths are less than one (1) foot, areas of 1% annual chance stream flooding where the contributing drainage area is less than one (1) square mile, or areas protected from the 1% annual chance flood by levees. No Base Flood Elevation or depths are shown within this zone.

Location of the Flooding Hazard

As a barrier island, the entirety of the City of Galveston is subject to flooding. Though a portion of the City is protected by the Seawall, it's important to note that this protection is only on the Gulf-facing side of the City; there is no such protection for the portion of the city that faces the Bay. See Map 6.3.8-1 for flood zone designations and boundaries, as defined by FEMA. This map also illustrates the location of the Galveston Seawall, the City's primary flood protection.

Map 6.3.8-1
Location of Special Flood Hazard Areas in Galveston
(Source: FEMA, NFIP)



Flood Control and Protection in Galveston

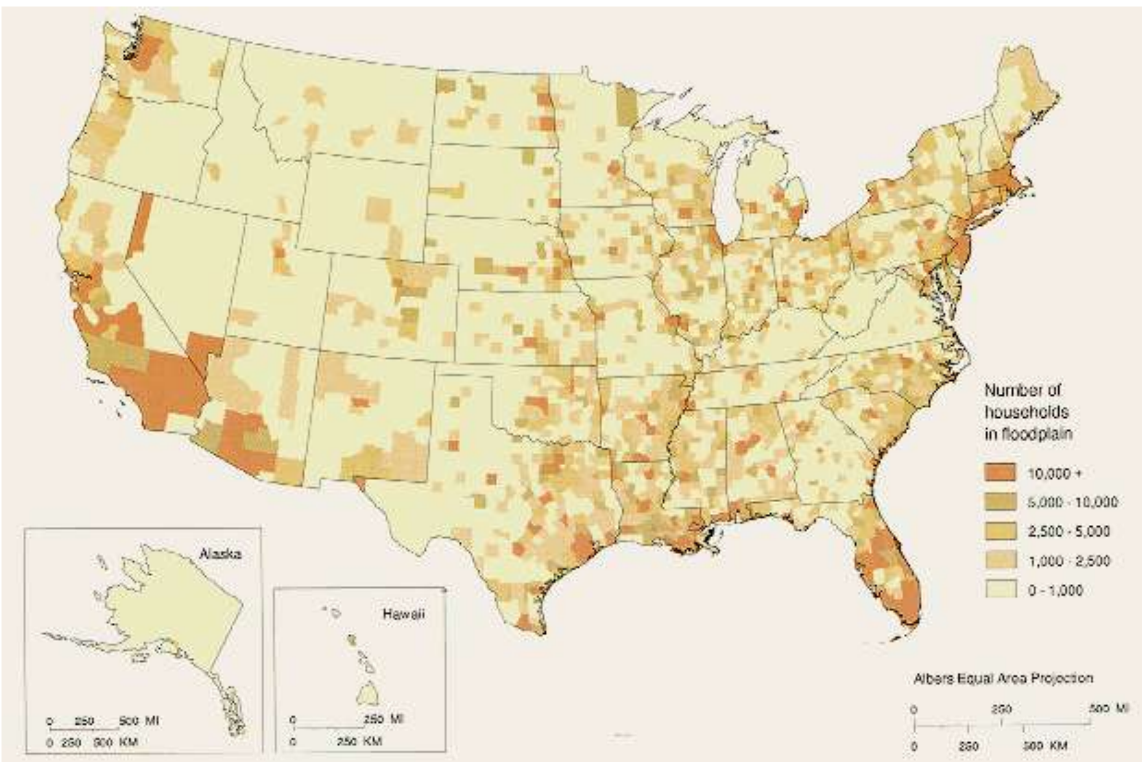
In the aftermath of the 1900 hurricane, physical changes were made to the Island to provide for flood protection. Portions of the Island itself were elevated, using fill dredged from Galveston Bay. Some portions of the Island were elevated to a height of 17' MSL. Note that this elevation occurred only on the eastern third of the Island, which was and remains the more densely populated portion. No such grade rising occurred on the West End, which remains largely at its natural elevation.

In addition to the elevation, construction of a seawall was commenced. The Galveston Seawall is a flood protection device that was built after the Galveston Hurricane of 1900 for protection from future storm surge inundation. Construction began in September 1902, and the initial segment was completed on July 29, 1904. From 1904 to 1963, the seawall was extended from 3.3 miles to over 10 miles long, its present length. It was constructed to approximately 17' high (MSL), and 16' thick at its base. The Seawall was listed in the National Register of Historic Places in 1977 and designated a National Civil Engineering Landmark by the American Society of Civil Engineers (ASCE) in 2001.

Severity of the Flooding Hazard

Flooding is the most prevalent hazard in the United States. Map 6.3.8-3 illustrates the number of households located in SFHAs across the country.

Map 6.3.8-3
Number of Households in the SFHA – Nationwide
(Source: FEMA)



Virtually the entirety of Galveston lies within an SFHA, as noted in Map 6.3.8-1. This includes the vast majority of residential structures, historic assets, critical facilities, and City-owned assets.

In Galveston, the threat of flooding from coastal storm surge inundation is very real. With more than 25 miles of Gulf-facing beach, and just as many miles of Bay-facing shore, the City is surrounded by water that is subject to hurricanes and other coastal storm events. Storm surge is a result of extreme winds pushing on the surface of the ocean, causing the water to rise to a height above normal sea level. When storm surge encounters land, it is measured in height above normal tide levels. Though a portion of the City is protected by the Seawall and has been artificially elevated, the majority of the land within the City's jurisdiction is not protected and has not been artificially elevated. It's worth noting that the Seawall was constructed to a height of 17' MSL; storm surge of any greater height could overtop the protection, leaving the entirety of the land within the City's jurisdiction vulnerable to storm surge inundation.

Table 6.3.8-1illustrates the traditional storm surge heights expected from various coastal storm categories.

Table 6.3.8-1
Saffir-Simpson Scale
(Source: NOAA)

Traditional Saffir-Simpson Scale		
Category	**Expected Wind Speed (mph)**	**Expected Surge Height (ft)**
Tropical Depression	0 – 38	0
Tropical Storm	39 – 73	0 - 3
Category 1 Hurricane	74 – 95	4 – 5
Category 2 Hurricane	96 – 110	6 -8
Category 3 Hurricane	111 – 130	9 – 12
Category 4 Hurricane	131 – 155	13 – 18
Category 5 Hurricane	>156	>18

In recent years there has been growing recognition and acknowledgement that the tradition Saffir-Simpson Scale is ineffective at estimating or predicting storm surge heights. Storm surge height is not strictly a function of wind speed and storm strength, but is influenced by a number of geographic variables. For example, though Hurricane Ike made landfall in Galveston as a Category 2 storm, with winds averaging 100 MPH, the storm surge experienced in Galveston was that of a Category 4 storm. The category assignment applied to Hurricane Ike, based on sustained wind speed, simply could not account for the severity of the hazards posed by the storm.

The following discussion was obtained from the National Hurricane Center's website:

> …many people suggested that the National Weather Service develop a storm surge specific scale as well as improve its forecasting of storm surge. It is acknowledged that there are some researchers who advocate developing another scale for hurricanes specifically geared toward storm surge impact by incorporating aspects of the system's size. However, the National Hurricane Center does not believe that such scales would be helpful or effective at conveying the storm surge threat. For example, if 2008's Hurricane Ike had made landfall in Palm Beach, Florida, the resulting storm surge would have been only 8', rather than the 20' that occurred where Ike actually made landfall on the upper Texas coast. These greatly differing surge impacts arise from differences in the local bathymetry (the shallow Gulf waters off of Texas enhance storm surge while the deep ocean depths off of southeastern Florida inhibit surge). The proposed storm surge scales that consider storm size do not consider these local factors that play a crucial role in determining actual surge impacts.
>
> The National Weather Service believes that a better approach is to focus directly on conveying the depth of inundation expected at the coast and inland. Because storm surge-induced flooding has killed more people in the United States in hurricanes than all other hurricane-related threats (freshwater flooding, winds, and tornadoes) combined since 1900 the National Oceanic and Atmospheric Administration is working to enhance the analysis and prediction of storm surge. Direct estimates of inundation are being communicated in the NHC's Public Advisories and in the Weather Forecast Office's Hurricane Local Statements. New ways of communicating the threat have also been developed. NHC's probabilistic storm surge product, which provides the likelihood of storm surge

values from 2 through 25 feet, became operational in 2009, and the NWS's Meteorological Development Laboratory is providing experimental, probabilistic storm surge exceedance products for 2010. In addition, coastal WFOs will provide experimental Tropical Cyclone Impacts Graphics in 2010; these include a qualitative graphic on the expected storm surge impacts. Finally, the NWS is exploring the possibility of issuing explicit Storm Surge Warnings, and such warnings could be implemented in the next couple of years. In all of these efforts, the NWS is working to provide specific and quantitative information to support decision-making at the local level.

Impact on Life and Property from the Flooding Hazard

Flooding is the most common natural disaster in the United States, and in the State of Texas. According to floodsmart.gov, in 2008 there were 35,248 NFIP claims paid in the State of Texas, totaling more than $2 billion. In 2009, there were 52 deaths attributable to flooding nationwide – 8 of which occurred in Texas.

A 1% flood event poses a significant threat to the City, its assets, and its residents. Structures that exist or are constructed in the SFHA are subject to damage from flood waters and floating debris, as well as to being undermined by erosion or scour. Moving water exerts hydrodynamic pressure on such structures, whereas still water exerts hydrostatic pressure. Both hydrostatic and hydrodynamic forces can cause serious damage, including complete destruction, of non-mitigated structures. Utility systems, such as HVAC systems, water and septic lines, and electrical systems, can be compromised, damaged or destroyed by flood waters, even if not completely inundated.

The best known flood event in Galveston's history is, of course, the 1900 Hurricane. This hurricane, also known as The Great Storm, redefined the City and its residents, and was the impetus for both the elevation of the Island and the construction of the Seawall.

At the time of the 1900 Storm, the highest point in the city of Galveston was 8.7' above sea level. The hurricane brought with it a storm surge of over 15 feet, which inundated the entire island. The surge knocked buildings off their foundations and the surf pounded them to pieces. Over 3,600 homes were destroyed and a wall of debris faced the ocean.

As severe as the damage to the city's buildings was, the human toll was even greater. Rescuers arrived to find the city completely destroyed. It is believed 8,000 people – at least 20% of the island's population - lost their lives. Estimates range from 6,000 to 12,000, with no possibility of determining an actual death toll. Most had drowned or been crushed as the waves pounded the debris that had been their homes hours earlier. Many survived the storm itself but died after several days trapped under the wreckage of the city, with rescuers unable to reach them. The rescuers could hear the screams of the survivors as they walked on the debris trying to rescue those they could. A further 30,000 were left homeless. More people were killed in this single storm than the total of those killed in all the tropical cyclones that have struck the United States since. As of 2009, more than 300 tropical systems have struck the US. The Galveston Hurricane of 1900 remains the deadliest natural disaster in U.S. history.

108 years later, almost to the day, Hurricane Ike devastated Galveston Island. Ike began impacting the City on Friday, September 12, 2008. Waves began crashing along the Seawall early that morning. By later that afternoon, the storm surge began overtopping the Seawall. Widespread flooding included downtown Galveston: 6' deep inside the Galveston County Courthouse, and the University of Texas Medical Branch at Galveston was devastated by flood waters. Wide scale flooding caused failures of UTMB systems and allowed mold to invade buildings. Students were

transferred to other Texas medical schools immediately after the storm while determinations were made about the future of the hospital and medical school. All emergency facilities were moved to the Houston medical center. It wasn't until August 1, 2009 that UTMB's emergency room was reopened.

In addition, the floodwaters of Ike also devastated the City's water and wastewater systems. The failure of both of these systems to function resulted in the delayed return of evacuated residents, due to unsafe and unsanitary living conditions on the Island. Most residents were prohibited from returning to their homes – those whose homes remained - for at least a week after the flood waters receded.

Occurrences of the Flooding Hazard

Table 6.3.8-2 depicts the occurrences of the flood hazard in the City of Galveston. The type of flooding and estimated damages, fatalities and injuries are noted (where data available). Note that this table is intended to be representative, and does not include all known occurrences of the flood hazard.

Table 6.3.8-2
Occurrences of the Flood Hazard in the City of Galveston
(Source: Galveston County Plan Update, NCDC)

Occurrences of the Flood Hazard in the City of Galveston					
Date	**Type of Flooding**	**Fatalities**	**Injuries**	**Estimated Damages**	**Notes**
05-30-1995	Urban	0	0	Unknown	Local police reported street flooding on the island.
07-30-1995	Tropical Storm Dean	0	0	$400,000 (affected area)	The center of Tropical Storm Dean made landfall near San Luis Pass and moved inland. Tides were three to 3.5 feet above normal and ranged from 3.3 feet at Morgan's Point to 4.8 feet at Pleasure Pier above lower low water.
04-25-1997	Flash	0	0	Unknown	5-7" rainfall caused street and bayou, flooding.
11-05-1997	Flash	0	0	$20,000	Heavy rain combined with high tides caused severe street flooding in the eastern half of Galveston Island.
06-29-1998	Flash	0	0	Unknown	Harborside Drive, 19th Street, 30th Street, 35th Street, and 50th Streets impassable due to high water.
08-21-1998	Tropical Storm Charley	0	0	$25,000	Beach erosion accounted for the damage estimates. Tides ran 2-3 feet above predicted astronomical levels. Most areas across SE Texas averaged 2-4 inches of rain fall, however locations to the coast received 4-6 inches.
09-07-1998	Tropical Storm Frances	2	0	$287 M (declared area)	On the beach front at Galveston Pleasure Pier the tides rose above 4 feet above MLLW on Wednesday afternoon and remained above this level until the Friday afternoon. The maximum level was reached on Thursday evening when the gauge read around 7 feet above MLLW or about 4.5 feet above the predicted levels. In Galveston Bay a similar even took place. With tides above 4 feet MLLW for 36 to 48 consecutive hours and winds in excess of 25 mph through the same period led to the destructive waves along the beach front. These destructive waves resulted in most of the dune systems from High Island to Sargent, Texas being almost completely destroyed. Over 4 inches of rain fell over all of the Houston/Galveston County Warning area. With tides already running 4 to 6 feet above normal the runoff from the rains was not able to easily runoff into the bays thus resulting in more widespread flooding of inland creeks and bayous especially early Friday morning. Most of the damage was along the coast and around Galveston Bay where high tides and winds destroyed dunes and personal property.
06--2001	Tropical Storm Allison	0	0	Unknown	Flooding from Tropical Storm Allison.
08-15-2002	Flash	0	0	$100,000	Water in cars and businesses, streets closed. Island received more than 11 inches of rain.

Occurrences of the Flood Hazard in the City of Galveston					
Date	**Type of Flooding**	**Fatalities**	**Injuries**	**Estimated Damages**	**Notes**
10-08-2002	Flash	0	0	$15,000	Roads flooded and impassable on Galveston Island after almost 3.50 inches of rain in 2 1/2 hours.
07-14-2003	Hurricane Claudette	0	0	$10.9M (declared area)	Major beach erosion was observed from High Island to Freeport. Large geo-tubes on Galveston Island and the Bolivar Peninsula did significantly reduce erosion. Coastal roads along the west end of Galveston Bay were under water due to tidal flooding.
08-30-2003	Tropical Storm Grace	0	0	$50,000	Heavy rainfall between 6 and 12 inches was observed from extreme eastern Galveston County to across the Bolivar Peninsula and northward into Chambers and portions of Liberty Counties.
09-23-2005	Hurricane Rita	0	0	$60,000 (City-specific)	Dunes protecting many beach houses along the West End of Galveston Island were washed away. Large geo tubes along portions of the West End of Galveston Island did reduce erosion in areas where they were installed. Most flooding was due to high tides along Galveston Island and the Bolivar Peninsula. Most of this flooding actually occurred near the time of landfall as water in Galveston Bay was pushed south out of the Bay onto the north facing shores of the island and the peninsula.
08-19-2006	Flash	0	0	$10,000	Flooding across the East End of Galveston Island and in The Strand area.
10-16-2006	Coastal	0	0	$75,000	Coastal flooding lead to high water in Galveston near Offatt's Bayou and 61st Street.
09-13-2008	Hurricane Ike	16 unaccounted for residents	numerous	$200M+	The unusually large storm produced an unusually large hurricane force wind field. The large wind field caused tides around Galveston Island to rise as much as nine feet 24 hours before the storm made landfall. Complete tide gauge records for this area are unavailable since many of the sensors failed from salt water intrusion and large wave action, although ground assessment teams determined that the surge was generally between 15 and 20 ft. Storm surge levels on Galveston Island and on the west side of Galveston Bay are estimated to be between 10 and 15 ft.

Probability of Future Occurrences of the Flooding Hazard

Given that Galveston is a barrier island with more than 95% of its jurisdiction located within the Special Flood Hazard Area, the probability of future occurrences of flooding is High.

6.3.9 Hazardous Materials Incident (Fixed Site and Transport)

Description of the Hazardous Materials Incident Hazard

A hazardous material is a biological, chemical or physical agent with the potential to cause harm to the environment or people on its own or when combined with other factors or materials. For the purposes of this mitigation plan, this hazard will include fixed site facilities, pipelines, and transportation incidents.

Hazardous materials incidents are technological (meaning non-natural hazards created or influenced by humans) events that involve large-scale accidental or intentional releases of chemical, biological, or radiological (nuclear) materials.

Pipeline incidents are typically incidents in which the pipeline is breached or fails. An estimated 2.2 million miles of pipelines carry hazardous materials throughout the United States – more than 77,000 miles of which is in Texas. Pipelines transport natural gas, crude or refined oils, fuels, and petrochemical products. Some pipelines also transport liquefied gases, such as carbon dioxide.

Hazardous materials come in the form of explosives, flammable and combustible substances, toxic releases and waste materials. These substances are most often released as a result of transportation accidents or because of chemical accidents in plants. Hazardous materials in various forms can cause death, serious injury, long-lasting health effects, and damage to buildings, homes, and other property. Many products containing hazardous chemicals are used and stored in homes routinely. These products are also shipped daily on the nation's highways, railroads, waterways, and pipelines.

Hazardous materials are monitored and recorded by the US Environmental Protection Agency (ESP) through the Toxics Release Inventory (TRI), which is a publically accessible database that contains information on toxic chemical releases and other hazardous materials activities. Data is reported annually by certain industry groups and various federal agencies. This inventory was established under the Emergency Planning and Community Right-to-Know Act of 1986 (EPCRA) and later expanded by the Pollution Prevention Act of 1990.

Each year, facilities that meet specified thresholds must report their releases and other waste management activities for listed toxic chemicals to the EPA and to their State or tribal entity. A facility must report incidents that meet the following criteria:

1. The facility falls within one of the following industrial categories:
    a. Manufacturing,
    b. Metal mining,
    c. Coal mining,
    d. Electric generating facilities that combust coal and/or oil,
    e. Chemical wholesale distributors,
    f. Petroleum terminals and bulk storage facilities,
    g. RCRA Subtitle C treatment, storage and disposal (TSD) facilities, and
    h. Solvent recovery services;
2. Has 10 or more full-time employees (or equivalent); and
3. Manufactures or processes more than 25,000 pounds or uses more than 10,000 pounds of any listed chemical during the calendar year. Persistent, bioaccumulative and toxic (PBT)

chemicals are subject to different thresholds of 10 pounds, 100 pounds, or 0.1 grams, depending on the chemical.

Tier 2 data is a publicly available database from the Texas Department of State Health Services Tier 2 Chemical Reporting Program. Under the community right-to-know regulations imposed at the state and federal levels, all facilities that store significant quantities of hazardous chemicals must share this information with state and local emergency responders and planners. Facilities in Texas share this information by filing annual hazardous chemical inventories with the state, Local Emergency Planning Committees (LEPCs), and local fire departments. The Texas Tier 2 reports contain facility identification information and detailed chemical data about the hazardous materials stored at the facility.

A facility must report chemicals to the Tier 2 database if it meets the following criteria:

1. Any company using chemicals that could present a physical or health hazard, or
2. If an industry has an Occupational Safety and Health Administration (OSHA) deemed chemical that exceeds the appropriate threshold at any point in time. These chemicals may be on a list of 356 Extremely Hazardous Substances (EHS), or may be one of the 650,000 reportable hazardous substances that do not appear on the EHS list.

Hazardous Materials pose a secondary event risk to communities when they are involved in transportation accidents. Transport by ground, rail and sea is a common occurrence in the US.

Location of the Hazardous Materials Incident Hazard

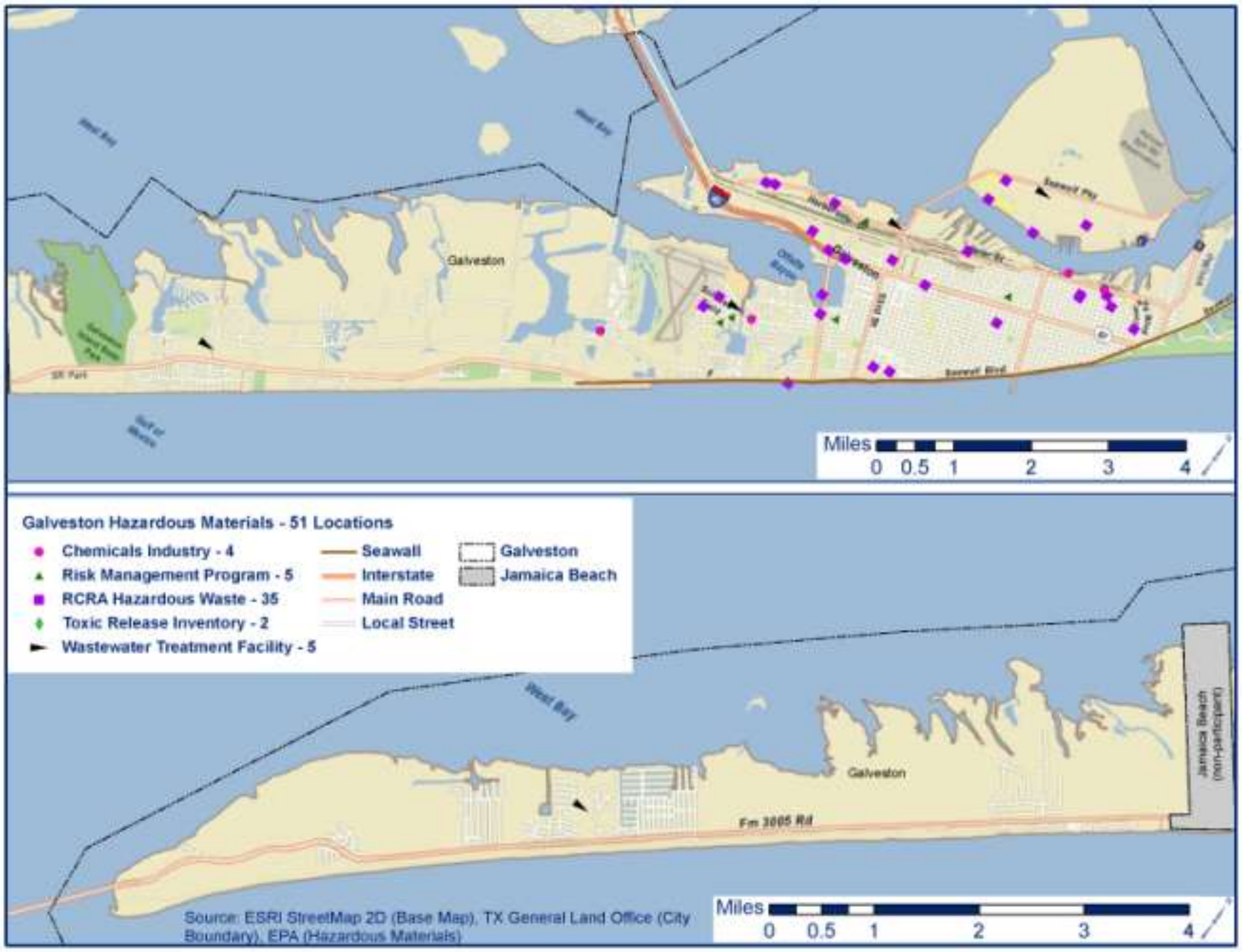
Galveston is home to UTMB, which is both a major medical center and a research university. As such, UTMB routinely handles significant quantities of hazardous materials. UTMB's many clinics, laboratories, and research facilities use a variety of hazardous materials. The handling and storage of hazardous materials are addressed in the *UTMB Safety Manual*. The *UTMB Safety Manual* instructs laboratories to develop an inventory of their chemicals.

The University's Environmental Health and Safety Service is responsible for administering the hazardous waste management program at UTMB. Chapter 10 of the *UTMB Safety Manual* discusses the types of hazardous waste generated by UTMB. The manual notes that almost all laboratory chemicals are considered hazardous waste when discarded. The manual provides instructions for the management of hazardous waste. UTMB generates about an average of 58 tons of hazardous waste annually. The hazardous waste generated by UTMB facilities is appropriately handled and treated by incineration.

UTMB manages its radiological waste in accordance with the Texas Radioactive Substances Rules. UTMB developed a *Radiation Safety Manual* to address the handling and disposal of radioactive material. All radioactive waste must be segregated and disposed of according to guidelines in the *Radiation Safety Manual*. Some radioactive wastes are released into the sanitary sewage system when allowed under regulations in the UTMB policy *Disposal of Hazardous Waste*. Radioactive waste materials that are soluble or dispersible in water can be released into the sanitary sewage system. Certain materials listed in the *Radiation Safety Manual* are prohibited from sewage disposal because of their chemical or biological nature.

Map 6.3.9-1 shows the location of 51 fixed site hazardous material facilities in the City. Note that all fixed site facilities are located on the east end of the island, excepting one wastewater treatment facility.

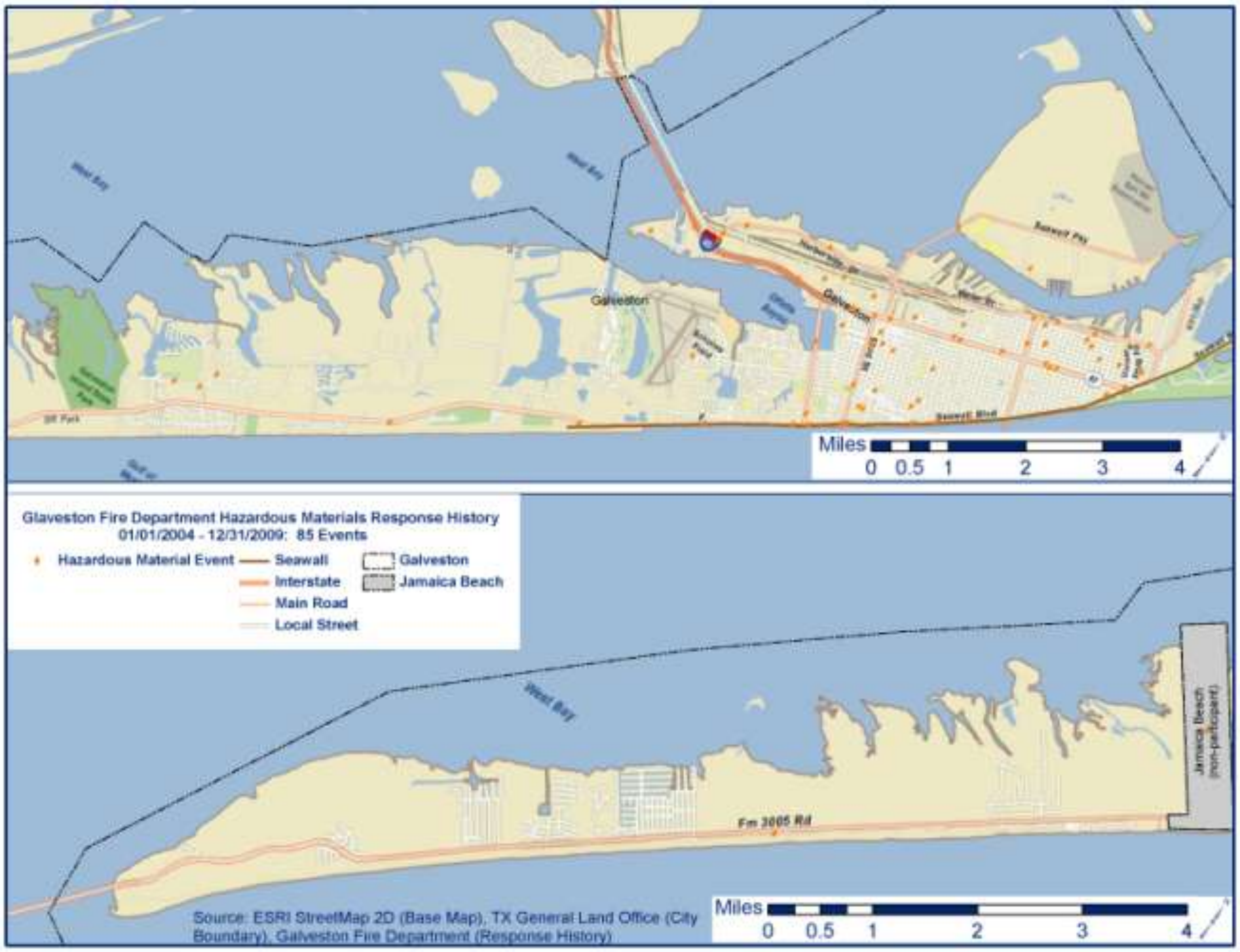
Map 6.3.9-1
Hazardous Materials Facilities
(Source: ESRI, EPA, City of Galveston)



Map 6.3.9-2 shows the location of hazardous materials lines and pipelines in the City of Galveston. **Please note that this information is sensitive and proprietary, and is redacted from public versions of the plan.**

Map 6.3.9-3 shows the locations of hazardous materials incidents handled by the Galveston Fire Department between January 2004 and December 2009. A total of 85 incidents offered in that 5 year period.

Map 6.3.9-3
Location of Hazardous Materials Incident Responses in Galveston
(Source: ESRI, GLO, Galveston Fire Department)



Severity of the Hazardous Materials Incident Hazard

The threat from the hazardous materials incident is to structures located along transmission lines and transportation routes in the City. There are critical facilities located along these routes.

The severity of this hazard is a range. Minor incidents would likely cause no damage and little disruption. Major incidents could have fatal and disastrous consequences. The severity of a hazardous material release relates primarily to its impact on human safety and welfare and on the threat to the environment.

Threat to Human Safety and Welfare

- Poisoning of water or food sources and/or supply
- Presence of toxic fumes or explosive conditions
- Damage to personal property
- Need for the evacuation of people
- Interference with public or commercial transportation

Threat to the environment

- Injury or loss of animals or plants or habitats that are of economic or ecological importance such as; commercial, recreation, or subsistence fisheries (marine plants, crustaceans, shellfish, aquaculture facilities) or livestock; seal haul outs; and marine bird rookeries
- Impact to ecological reserves, forests, parks, archaeological, and cultural sites

Galveston's concentrated east end could increase the severity of any incident involving hazardous materials. Hazardous materials could come into contact with more people and structures before they were able to dissipate, which could increase the severity of the event in terms of exposure rates. Depending on the hazardous materials involved, the location of the incident, and the weather conditions at the time of the incident, Galveston could experience a routine incident or a devastating incident involving hazardous materials.

Impact on Life and Property from the Hazardous Materials Incident Hazard

Hazardous materials incidents refer to uncontrollable releases of hazardous materials at a facility, which poses a risk to the health, safety, property, and the environment. The most well-known example of a large-scale fixed-site hazardous materials incident is that which occurred at the Union Carbide plant in Bhopal, India in 1984. This incident caused 2,500 deaths and injuries to many others. More recently, in June 2010, 2 pipeline incidents in as many days killed 3 people and injured 3 others. Both incidents occurred in Texas.

Although incidences on the Bhopal scale are rare, smaller scale incidents–those requiring a response and evacuation or other protective measures–are relatively common.

Depending on the severity of the incident, the potential impact to life and property is great in Galveston. Incidents can cause multiple fatalities, completely shut down facilities (and the surrounding area) for days or weeks, and cause extensive property and infrastructure damage. Weather conditions can directly impact how a hazardous materials incident develops or can be the initiator of the incident, as in the case of unprotected facilities inundated by storm surge. Non-compliance with fire and building codes can substantially increase damage from an incident, as the containment features may not be up to standards.

Occurrences of the Hazardous Materials Incident Hazard

Table 6.3.9-1 lists occurrences of pipeline accidents in or near the City of Galveston from 2003 – 2008.

Table 6.3.9-1
Pipeline Accidents, 2003 – 2008
(Source: Texas Railroad Commission)

Pipeline Accidents in or near Galveston, 2003-2008			
Incident Date	**Operator**	**Operator Property Damage**	**Notes**
10-22-2003	Texas Gas Service	$55,009	
12-19-2003	Texas Gas Service	$0	No damages reported
02-02-2004	Texas Gas Service	$29,156	
02-09-2004	Texas Gas Service	$24,564	
05-12-2005	Texas Gas Service	$2,626	
07-07-2005	Texas Gas Service	$128,585	
07-11-2005	Texas Gas Service	$355	
09-06-2005	Texas Gas Service	$1,143	
05-22-2006	Texas Gas Service	$3,120	
12-24-2006	St. Mary's Land & Exploration	$0	No damages reported
12-24-2006	St. Mary's Land & Exploration	$0	No damages reported
06-02-2007	Texas Gas Service	$0	No damages reported
01-21-2008	Texas Gas Service Company	$0	No damages reported
03-06-2008	Texas Gas Service Company	$25,000	
04-09-2008	Texas Gas Service Company	$369	
06-10-2008	Texas Gas Service Company	$20,524	
06-18-2008	Texas Gas Service Company	$8,596	

Between January 2004 and December 2009, the Galveston Fire Department responded to 15 incidents involving train derailments. Of these 15 incidents, 8 involved some type of hazardous material or the potential for hazardous material incident.

During this same timeframe, the Galveston Fire Department also responded to 19 semi marine vessel incidents. While none of these involved hazardous materials, the likelihood is that an incident will occur that will involve hazardous materials.

Table 6.3.9-2 shows the more significant hazardous materials incidents responded to by the Galveston Fire Department from January 2004 through December 2009. This list is intended to be illustrative rather than all-inclusive. For a complete listing, see Appendix O.

Table 6.3.9-2
Hazardous Materials Incidents – 2004-2009
(Source: Galveston Fire Department)

Hazardous Materials Incidents, 2004-2009			
Hazardous Material	**Container**	**Quantity Released**	**Released Into**
Natural Gas	Fixed container	10 cubic feet	Air
Compressed Methane	Unknown	2 cubic feet	Air
Natural Gas	Hose	14 liters	Air
Natural Gas	Pipe or pipeline	125 cubic feet	Air

Hazardous Materials Incidents, 2004-2009			
Hazardous Material	**Container**	**Quantity Released**	**Released Into**
Natural Gas	Pipe or pipeline	500 cubic feet	Air
Sulphur	Unknown	22 pounds	Unknown
Hydraulic Fluid	Unknown	2 gallons	Unknown
Methyl Ethly Ketone	Drum	17 gallons	Confined – no environmental impact
Calcium Chloride	Bag or sack	100 pounds	Confined – no environmental impact
Formalin	Tank or silo	150 gallons	Air, water and ground
Naphtha	Product tank on vehicle	25 gallons	Air and ground
Hydrochloric Acid	Can or bottle	64 liquid ounces	Air and ground

Probability of Future Occurrences of the Hazardous Materials Incident Hazard

Occurrences of the hazardous materials incident hazard are often dependent on external factors. An incident can be caused intentionally or accidentally, and may or may not involve human action. Major disaster events can be a major cause, as inundation by flood water or damage from high winds may result in a hazardous materials release. This is usually caused or exacerbated by damage to infrastructure, such as water supply/distribution and waste water treatment facilities.

It's almost impossible to predict the statistical probability of future occurrences of the hazardous materials incident hazard, as there are simply too many variables, including human behavior. However, the number of possible points of origin for such an incident must be taken into account. Therefore, the probability of future occurrence can be rated as High.

6.3.10 Lightning

Description of the Lightning Hazard

Lightning is an atmospheric discharge of electricity accompanied by thunder, which typically occurs during thunderstorms, and sometimes during volcanic eruptions or dust storms. In the atmospheric electrical discharge, a leader of a bolt of lightning can travel at speeds of 130,000 MPH, and can reach temperatures approaching 54,000 °F, hot enough to fuse silica sand into glass. There are some 16 million lightning storms in the world every year.

Lightning can also occur within the ash clouds from volcanic eruptions, or can be caused by violent forest fires which generate sufficient dust to create a static charge.

Lightning rapidly heats the air in its immediate vicinity to about 36,000 °F - about three times the temperature of the surface of the sun. This compresses the surrounding air and creates a supersonic shock wave, which decays to an acoustic wave that is heard as thunder.

How lightning initially forms is still a matter of debate: Scientists have studied root causes ranging from atmospheric conditions (wind, humidity, friction, and atmospheric pressure) to the impact of solar wind and accumulation of charged solar particles. Ice inside a cloud is thought to be a key element in lightning development, and may cause a forcible separation of positive and negative charges within the cloud, thus assisting in the formation of lightning.

Some lightning strikes exhibit particular characteristics; scientists and the general public have given names to these various types of lightning. The lightning that is most-commonly observed is streak lightning. This is nothing more than the return stroke, the visible part of the lightning stroke. The majority of lightning occurs inside a cloud and is not observed during a thunderstorm.

The following are descriptions of various terms used to describe lightning, both scientific and common usage:

- **Cloud-to-Ground Lightning.** This is the best known and second most common type of lightning. Of all the different types of lightning, it poses the greatest threat to life and property since it strikes the ground. Cloud-to-ground lightning is a lightning discharge between a cumulonimbus cloud and the ground. It is initiated by a leader stroke moving down from the cloud.
- **Bead Lightning**. Bead lightning is a type of cloud-to-ground lightning which appears to break up into a string of short, bright sections, which last longer than the usual discharge channel. It is relatively rare. Several theories have been proposed to explain it; one is that the observer sees portions of the lightning channel end on, and that these portions appear especially bright. Another is that, in bead lightning, the width of the lightning channel varies; as the lightning channel cools and fades, the wider sections cool more slowly and remain visible longer, appearing as a string of beads.
- **Ribbon Lightning.** Ribbon lightning occurs in thunderstorms with high cross winds and multiple return strokes. The wind will blow each successive return stroke slightly to one side of the previous return stroke, causing a ribbon effect.
- **Staccato Lightning**. Staccato lightning is a cloud to ground lightning strike which is a short-duration stroke that appears as a single very bright flash and often has considerable branching.

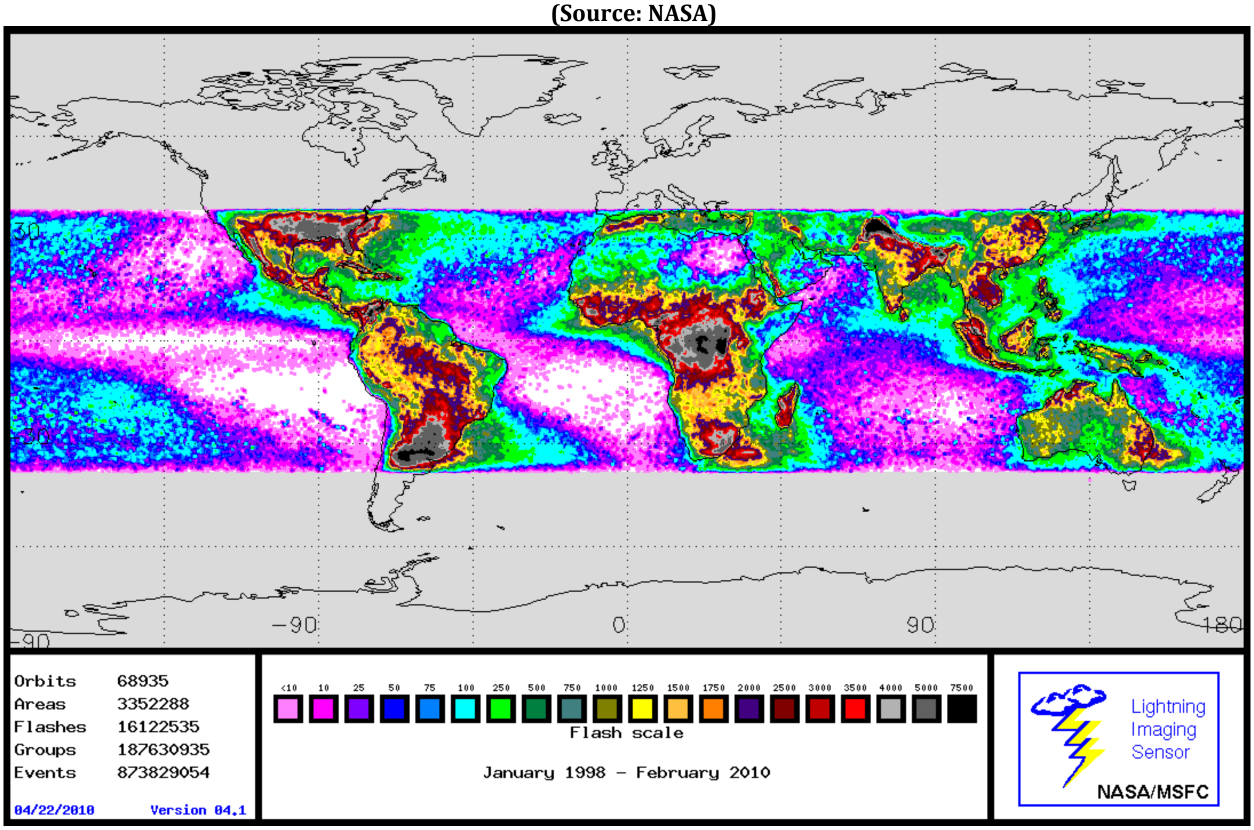
- **Ground-to-Cloud Lightning.** Ground-to-cloud lightning is a lightning discharge between the ground and a cumulonimbus cloud initiated by an upward-moving leader stroke. It is much rarer than cloud-to-ground lightning. This type of lightning forms when negatively charged ions called the stepped leader rises up from the ground and meets the positively charged ions in a cumulonimbus cloud. Then the strike goes back to the ground as the return stroke.
- **Cloud-to-Cloud Lightning.** Lightning discharges may occur between areas of cloud without contacting the ground. When it occurs between two separate clouds it is known as inter-cloud lightning and when it occurs between areas of differing electric potential within a single cloud, it is known as intra-cloud lightning. Intra-cloud lightning is the most frequently occurring type.
- **Heat Lightning**. Heat lightning is a common name for a lightning flash that appears to produce no thunder because it occurs too far away for the thunder to be heard. The sound waves dissipate before they reach the observer.
- **Dry Lightning**. Dry lightning is a term used for lightning that occurs with no precipitation at the surface. This type of lightning is the most common natural cause of wildfires. Pyrocumulus clouds produce lightning for the same reason that it is produced by cumulonimbus clouds. When the higher levels of the atmosphere are cooler, and the surface is warmed to extreme temperatures due to a wildfire, volcano, etc., convection will occur, and the convection produces lightning. Therefore, fire can beget dry lightning through the development of more dry thunderstorms which cause more fires.

Location of the Lightning Hazard

Lightning is a non-spatial hazard, and has the potential to affect the entire planning area equally.

Figure 6.3.10-1 illustrates the intensity of lightning flashes on the surface of the Earth, as observed by the NASA/MFSC Lightning Imaging Sensor. This data was collected from January 1998 through February 2010. In general, the darker the color in the figure, the more intense the lightning flash.

Figure 6.3.10-1
Global Lightning Flash Intensity
(Source: NASA)



Severity of the Lightning Hazard

The National Weather Service (NWS) uses a Lightning Activity Level scale to indicate the frequency and character of cloud-to-ground (C/G) lightning, the most common form of lightning on Earth. The scale uses a range of 1 – 6, with 6 being the high end of the scale. Table 6.3.10-1 provides this severity scale.

Table 6.3.10-1
Lightning Activity Level
(Source: http://www.crh.noaa.gov/gid/?n=fwfintro)

Lightning Activity Level Scale					
Rank	**Cloud and Storm Development**	**Areal Coverage**	**Counts C/G per 5 Minutes**	**Counts C/G per 15 Minutes**	**Average C/G per Minute**
1	No Thunderstorms	None	None	None	None
2	Cumulus clouds are common but only a few reach the towering stage. A single thunderstorm must be confirmed in the rating area. The clouds mostly produce virga but light rain will	<15%	1-5	1-8	<1

Lightning Activity Level Scale					
Rank	**Cloud and Storm Development**	**Areal Coverage**	**Counts C/G per 5 Minutes**	**Counts C/G per 15 Minutes**	**Average C/G per Minute**
	occasionally reach ground. Lightning is very infrequent.				
3	Cumulus clouds are common. Swelling and towering cumulus cover less than 2/10 of the sky. Thunderstorms are few, but 2 to 3 occur within the observation area. Light to moderate rain will reach the ground, and lightning is infrequent.	15% to 24%	6-10	9-15	1-2
4	Swelling cumulus and towering cumulus cover 2-3/10 of the sky. Thunderstorms are scattered but more than three must occur within the observation area. Moderate rain is commonly produced, and lightning is frequent.	25% to 50%	11-15	16-25	2-3
5	Towering cumulus and thunderstorms are numerous. They cover more than 3/10 and occasionally obscure the sky. Rain is moderate to heavy, and lightning is frequent and intense.	>50%	>15	>25	>3
6	Dry lightning outbreak. (LAL of 3 or greater with majority of storms producing little or no rainfall.)	>15%	None	None	None

Galveston frequently experiences moderate to severe lighting, as a consequence of its relative location in a sub-tropical climate.

Impact on Life and Property from the Lightning Hazard

Lightning is the leading cause of weather-related personal injuries. Perhaps because lightning is a common weather phenomenon, most people do not take the associated risks of exposure to lightning as seriously as they should.

Lightning is a major cause of storm related deaths in the U.S., out pacing hurricanes and tornados in most years. A lightning strike can result in a cardiac arrest (heart stopping) at the time of the injury, although some victims may appear to have a delayed death a few days later if they are resuscitated but have suffered irreversible brain damage.

On average, for every person actually struck by lightning, 10 additional people are affected by the strike.

According to *Storm Data*, a National Weather Service publication, over the last 30 years the U.S. has averaged 58 *reported* lightning fatalities per year. Due to under reporting, the figures are more realistically at least 70 deaths per year. Only about 10% of people who are struck by lightning are killed, leaving 90% with various degrees of disability.

Table 6.3.10-2 illustrates statistics from the National Weather Service. Assuming a US population of 300 million (based on the 2008 Census estimate), the NWS has calculated the likelihood of the average person being struck or killed by lightning.

Table 6.3.10-2
Injury or Death from Lightning Probability Statistics
(Source: NWS - http://www.lightningsafety.noaa.gov/medical.htm)

Odds of Becoming a Victim of Lightning	
Characteristic	**Probability or Statistic**
Number of Deaths Reported	60
Estimated Number of Deaths	70
Number of Injuries Reported	340-400
Estimated Number of Injuries	540-600
Odds of Being Struck by Lightning in a Given Year (using reported numbers)	1 in 750,000
Odds of Being Struck by Lightning in a Given Year (using estimated numbers)	1 in 500,000
Odds of Being Struck by Lightning in Average Lifetime (80 years)	1 in 6,250
Odds of Being Affected by Someone Else Being Struck	1 in 625

While approximately one third of all injuries occur during work, workers compensation companies are often reluctant to acknowledge the injury or pay related medical expenses. An estimated third of injuries occur during recreational or sports activities. The last third occurs in diverse situation, including injuries to those inside buildings.

Those struck by lightning report a variety of affects, including:

- Personality changes, likely due to frontal lobe damage
- Fatigue
- Brain and nervous system damage
- Headaches
- Ringing in the ears
- Dizziness
- Nausea and vomiting
- Sleep difficulties
- Seizures
- Chronic pain

In addition to the impact lightning can have on people, lightning can have significant impact on property, including utility infrastructure, such as lift stations and electrical sub-stations. Lightning is the leading natural cause of wildfires, and can lead to structure fires as well. The historic structures and districts are particularly vulnerable, as they are primarily wood-frame construction and are closer together than modern residences.

The Lightning Protection institute, a non-profit organization dedicated to promoting lightning safety and protection, conducted a study that demonstrates that:

- 32% of lightning strikes hit roofs and projections such as satellite dishes or chimneys;
- 29 % of lightning strikes hit overhead power lines and phone lines;
- 29% of lightning strikes hit television antennas; and
- 10% of lightning-strikes hit trees near structures.

On average, lightning strikes cause 30% of the church fires and at least 18% of lumberyard fires in the United States annually. They also cause significant losses to more than 18,000 houses and 12,000 other buildings.

In addition to direct losses such as property damage to buildings, a lightning strike may result in the indirect losses that often accompany the destruction or damage of buildings and their contents. For example, municipalities rely upon the integrity of their structures as they provide services to their communities. A stroke of lightning to an unprotected building that houses the police or fire station may result in an interruption of vital services to the community. The consequences of such an interruption can range from the public's loss of confidence to a citizen's death when a department is unable to respond to an emergency call.

Occurrences of the Lightning Hazard

As a barrier island in a sub-tropical climate, Galveston is frequently subject to lightning. While no major assets have been damaged by lightning, this is likely due to the lightning protection systems in place to protect city-owned assets.

Probability of Future Occurrences of the Lightning Hazard

Based on the historical frequency of occurrence of lightning, the probability of future occurrence of the lightning hazard is High.

6.3.11 Sea Level Change

Description of the Sea Level Change Hazard

Note: While the severity and occurrence of this hazard is subject to debate and disagreements, the City of Galveston maintains that this phenomenon is occurring and does pose a threat to the City. Though the US, as a matter of national policy, does not concur with all scientific findings and research, the City believes that this hazard is occurring and does pose a threat to the City, its assets and residents, particularly when considered in conjunction with other coastal hazards, such as erosion and subsidence. Therefore, this hazard profile will be included in this Hazard Mitigation Plan.

For purposes of this mitigation plan, sea level change is defined as changes in the height of the sea in relation to the height of the land, and is considered a separate, yet inextricably related, hazard from coastal erosion, retreat and subsidence.

Local mean sea level (LMSL) is defined as the height of the sea with respect to a land benchmark, averaged over a period of time (such as a month or a year) long enough that fluctuations caused by waves and tides are smoothed out. One must adjust perceived changes in LMSL to account for vertical movements of the land, which can be of the same order (millimeters/year) as sea level changes. Some land movements occur because of isostatic adjustment of the mantle to the melting of ice sheets at the end of the last ice age. The weight of the ice sheet depresses the underlying land, and when the ice melts away the land slowly rebounds. Atmospheric pressure, ocean currents and local ocean temperature changes also can affect LMSL.

Eustatic change (as opposed to local change) results in an alteration to the global sea levels, such as changes in the volume of water in the world oceans or changes in the volume of an ocean basin. Submergence refers to permanent flooding of the coast caused by a rise in global sea level and/or subsidence of the land. At many coastal sites, submergence is the most important factor responsible for land loss. How much land will be lost as a result of sea-level rise depends partly on how fast the water is rising. It has been estimated that each year global sea level rises about 1.8 mm (.07 inches) as a result of a worldwide increase in water volume. However, this value is substantially less than the total rise in relative sea level recorded at many tide gauges, so scientists have concluded that the remaining amount of relative sea-level rise is caused by land subsidence. At any coastal site the relative sea level includes the global sea-level component (eustasy), tectonic uplift or down warping, and at some locations subsidence that is the result of natural sediment compaction or subsidence induced by the withdrawal of subsurface fluids such as groundwater, oil, and natural gas. Land loss can also occur in those coastal areas that are experiencing uplift (relative fall in sea level) such as along the Pacific coast and parts of Alaska (e.g. Juneau). This is because storm surges and high waves continue to cause land loss.

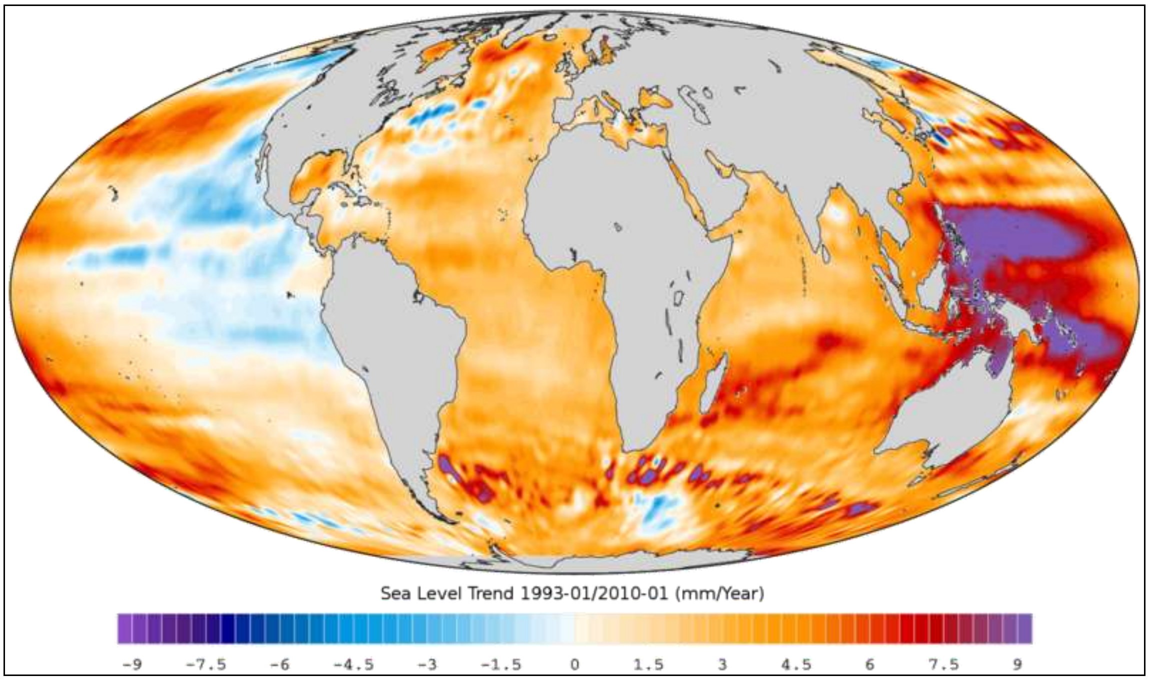
Not only is sea level rising in a relative sense at many coastal sites, statistical analyses of long-term records show that the present rates of relative sea-level rise are much greater than rates of submergence were for the past few thousand years. This discrepancy between historical and geological rates of submergence has been interpreted as evidence that atmospheric warming since the industrial revolution has caused thermal expansion of the oceans and melting of mountain glaciers and possibly the Antarctic ice sheet.

Location of the Sea Level Change Hazard

Changes in local sea level have the potential to occur anywhere in the world where the land meets the ocean. As a barrier island, the entirety of Galveston could be subject to the sea level change hazard.

The following map provides estimates of sea level rise based on measurements from satellite radar altimeters. The local trends were estimated using data from TOPEX/Poseidon (T/P), Jason-1, and Jason-2, which have monitored the same ground track since 1992, and were published by NOAA.

Figure 6.3.11-1
Sea Level Change, in millimeters per year, 1993-2010
(Source: http://ibis.grdl.noaa.gov/SAT/SeaLevelRise/LSA_SLR_maps.php)



As indicated by the color coding on the above map, the upper Texas Coast has experienced sea level changes of 1.5-4.5 millimeters since 1993.

Figure 6.3.11-2 shows areas of the US Atlantic and Gulf Coasts that would be flooded by a 10 meter (32.80 feet) rise in sea levels.

Figure 6.3.11-2
US Atlantic and Gulf Coasts Vulnerable to 10 Meter Sea Level Rise
(Source: USGS - http://pubs.usgs.gov/fs/fs2-00/)

The areas colored in red account for 25% of the US population.

Severity of the Sea Level Change Hazard

According to the USGS, global sea level and the Earth's climate are closely linked. The Earth's climate has warmed about 1°C (1.8°F) during the last 100 years. As the climate has warmed following the end of a recent cold period known as the "Little Ice Age" in the 19th century, sea level has been rising about 1 to 2 millimeters (.03 to .06 inches) per year due to the reduction in volume of ice caps, ice fields, and mountain glaciers in addition to the thermal expansion of ocean water. If present trends continue, including an increase in global temperatures caused by increased greenhouse-gas emissions, many of the world's mountain glaciers will disappear. For example, at the current rate of melting, all glaciers will be gone from Glacier National Park, Montana, by the middle of the next century. In Iceland, about 11 percent of the island is covered by glaciers (mostly ice caps). If warming continues, Iceland's glaciers will decrease by 40 percent by 2100 and virtually disappear by 2200.

Most of the current global land ice mass is located in the Antarctic and Greenland ice sheets. Complete melting of these ice sheets could lead to a sea-level rise of about 80 meters (262 feet), whereas melting of all other glaciers could lead to a sea-level rise of only one-half meter (1.64 feet). Table 6.3.11-1 illustrates the estimated potential maximum seal level rise from the total melting of present-day glaciers.

Note that 1 meter equates to 3.28 feet.

Table 6.3.11-1
Estimated Potential Maximum Sea Level Rise from Melting of All Present-Day Glaciers
(Source: USGS - http://pubs.usgs.gov/fs/fs2-00/)

Estimated Potential Sea Level Rise from Melting of All Present-Day Glaciers		
Location	**Estimated Volume (km^3)**	**Estimated Sea Level Rise (meters)**
East Antarctic Ice Sheet	26,038,200	64.80
West Antarctic Ice Sheet	3,262,000	8.06
Antarctic Peninsula	227,100	.46
Greenland	2,620,000	6.55
All other ice caps, ice fields, and valley glaciers	180,000	.45
Totals:	**32,328,300**	**80.32**

Galveston is a barrier island with an average elevation that ranges from 12 feet on the east end to 6 feet on the west end. An increase in sea level of only a few feet would result in a significant loss of land and elevation, and would increase the Island's vulnerability to coastal storms and coastal hazards.

Impact on Life and Property from the Sea Level Change Hazard

Reports, studies and data from the international scientific community seem to indicate that current and future sea level changes could be expected to have a number of impacts, particularly on coastal systems. Such impacts may include

- increased coastal erosion;
- higher storm-surge flooding;
- more extensive coastal inundation;
- changes in surface water quality and groundwater characteristics;
- increased loss of property and coastal habitats;
- increased flood risk and potential loss of life;
- loss of cultural resources and values;
- impacts on agriculture and aquaculture through decline in soil and water quality; and
- loss of tourism, recreation, and transportation functions.

There is an implication that many of these impacts will be detrimental—especially for the three-quarters of the world's poor who depend on agriculture systems. However, owing to the great diversity of coastal environments; regional and local differences in projected relative sea level and climate changes; and differences in the resilience and adaptive capacity of ecosystems, sectors, and countries, the impacts will be highly variable in time and space.

Statistical data on the human impact of sea level rise is scarce. A study in the April, 2007 issue of *Environment and Urbanization* reports that 634 million people live in coastal areas within 30 feet of sea level. The study also reported that about two thirds of the world's cities with over five million people are located in these low-lying coastal areas. A sea-level rise of just 400 mm (15.74 inches) in the Bay of Bengal would put 11 percent of the Bangladesh's coastal land underwater, creating 7 to 10 million climate refugees.

In Galveston, sea level rise has slow-moving implications for the entire planning area. Galveston has a wide array of infrastructure, including water and sewer lines and vital roadways, which run parallel to the coast, and would be at risk of inundation if the water in the Gulf of Mexico continues to rise at its current rate. In addition, there are at least 25 residential structures that are seaward of the 200-foot line, and are likely to be affected by sea level rise sooner than others.

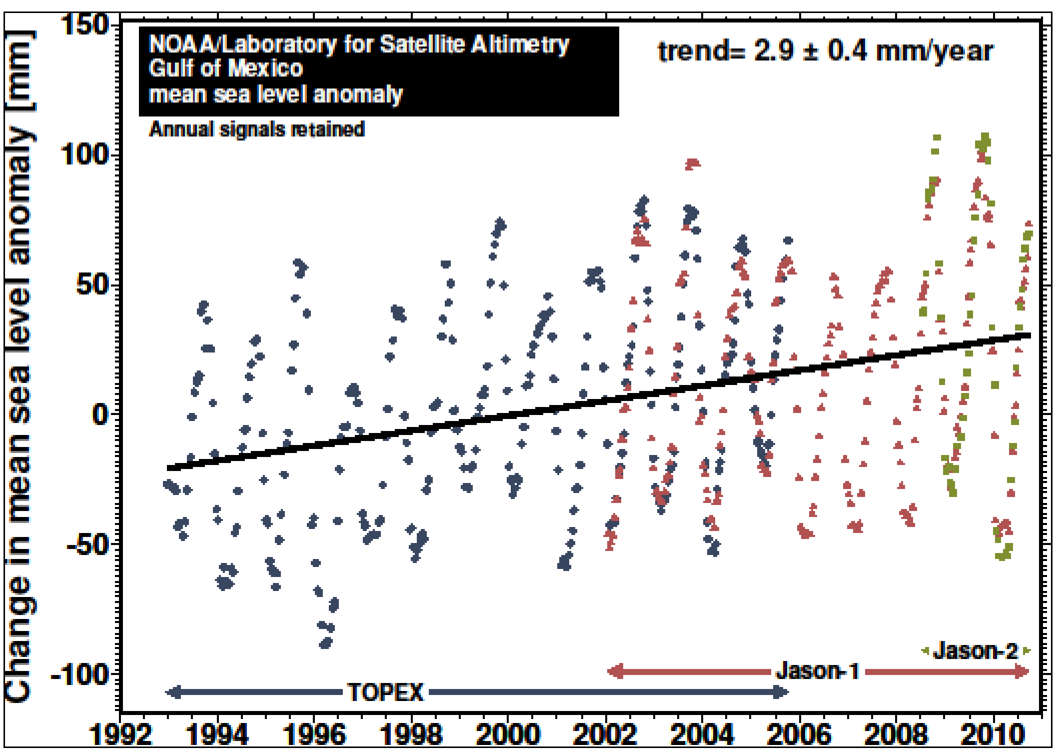
Occurrences of the Sea Level Change Hazard

Regardless of its cause, coastal submergence contributes to land loss in several ways. The most easily recognized effects of submergence are land losses caused by permanent flooding. The passive inundation of the shore typically expands estuaries, lakes, and lagoons at the expense of adjacent uplands and wetlands. The slope of the land surface and rate of sea level rise control the extent of permanent flooding. Steep slopes and low rates of sea-level rise produce negligible flooding, whereas low slopes and rapid rates of sea-level rise inundate such vast areas so rapidly that the submergence can be detected in a few decades. Rapid coastal submergence has been documented at Baytown, Texas near Houston and on the Mississippi Delta. Subsiding land areas experience greater and more prolonged flooding by salt water associated with storms. This means that storm surges of historical record would inundate larger areas if similar storms were to occur today. Eventually the repeated inundation by saltwater expands the flood zones and alters the predominant wetland plant assemblages. This occurs because salinities within the wetlands and estuaries increase, as they are permanently flooded. In many coastal regions the inundation of salt water actually accelerates wetland losses because both fresh-water and salt-water marshes are destroyed faster than new wetlands are created. The intolerant fresh-water marshes are killed by salt-water, whereas the salt-water marshes are drowned and converted to open water.

Submergence also accelerates coastal erosion because it facilitates greater inland penetration of storm waves. An example is retreat of the bluffs at Calvert, Maryland on the Chesapeake Bay. As a result of submergence, some bluffs that were not previously reached by storm waves are subjected to erosion. In addition to accelerated land loss, coastal submergence causes intrusion of salt-water into coastal aquifers and into the rivers that empty into the estuaries. Submergence also changes surface drainage patterns, raises groundwater levels, and causes areas even above sea level to pond water and to be poorly drained. Around Pamlico Sound, North Carolina, dead trees are an indication of rising freshwater levels caused by the relative rise in sea level.

As a barrier island, Galveston is subject to the effects of seal level rise. Sea level rise is a large scale, global hazard. The data that is available is on a large scale rather than on a local level. For example, NOAA tracks changes in sea level by body of water, such as the Caribbean Sea or the Gulf of Mexico. Therefore, all occurrence data that is available for this hazard as it relates to Galveston is at the level of the Gulf of Mexico. The image below indicates the change in sea level rise in the Gulf of Mexico from 1992 through 2010, which is the most recent data available from NOAA. This data indicates an increase in sea level in the Gulf of Mexico of 2.9 mm per year (+/- 4 mm per year).

Figure 6.3.11.3
Mean Sea Level – Gulf of Mexico
(Source: NOAA)



Currently, the impact of sea level rise to Galveston is minimal. It is anticipated, as the sea level continues to rise, that this will change in the next decade or two, and that the impact to Galveston will increase as time goes on. It is anticipated that future updates to this plan will be able to provide more detailed data as the level rises and impacts are determined.

Probability of Future Occurrences of the Sea Level Change Hazard

Predicting the fate of our shorelines and coastal ecosystems is confounded by the diverse set of environmental forces and gradients that differ for each physical and biological setting. Areas along the Gulf Coast, for example, share the Gulf of Mexico but have different tidal regimes, energies and amplitudes, as well as different ecosystems, tropical and temperate. The frequency, periodicity, and intensity of tropical storm landfalls likewise varies across the Gulf basin. The degrees of coastal development and protection that have been applied by state and county as dictated by population, port facilities, or other priorities also differ.

Given that sea levels are in constant flux, and that Galveston is prone to both coastal erosion and subsidence, the probability of future occurrence of the sea level change hazard is High. While this hazard is slow developing, it is nevertheless fairly constant in its happening.

6.3.12 Terrorism

Description of the Terrorism Hazard

Terrorism is violence committed by groups or individuals in order to intimidate a population or government into granting their demands.

Defining what is and what is not terrorism has proven to be a difficult task. 22 USC defines terrorism in the following ways:

(1) the term “international terrorism” means terrorism involving citizens or the territory of more than 1 country;
(2) the term “terrorism” means premeditated, politically motivated violence perpetrated against noncombatant targets by subnational groups or clandestine agents;
(3) the term “terrorist group” means any group, or which has significant subgroups which practice, international terrorism;
(4) the terms “territory” and “territory of the country” mean the land, waters, and airspace of the country; and
(5) the terms “terrorist sanctuary” and “sanctuary” mean an area in the territory of the country—
(A) that is used by a terrorist or terrorist organization—
(i) to carry out terrorist activities, including training, fundraising, financing, and recruitment; or
(ii) as a transit point; and
(B) the government of which expressly consents to, or with knowledge, allows, tolerates, or disregards such use of its territory and is not subject to a determination under—
(i) section 2405(j)(1)(A) of the Appendix to title 50;
(ii) section 2371 (a) of this title; or
(iii) section 2780 (d) of this title.
(Source: *U.S. Code Title 22, Ch.38, Para. 2656f(d))*

Once thought the be a type of disaster event that did not happen on U.S. soil, the threat of terrorism has evolved into a main concern, with Americans now citing homeland security as a top priority. Whether setting off a nuclear attack, igniting a traditional or dirty bomb, poisoning water/food supplies, or attacking the public transportation system, terrorists are familiar with our nation’s vulnerabilities, and will manipulate them to inflict fear on the psyche of the American people.

There are a variety of methods by which terror can be inflicted on a population. These are discussed in Table 6.3.12-1.

Table 6.3.12-1
Methods of Implementation for Terrorism
(Source: *FEMA 386*)

Methods of Implementation for Terrorism				
Description	**Application Mode**	**Duration**	**Extent of Effects**	**Mitigating or Exacerbating Conditions**
Conventional Bomb/ Improvised Explosive Device	Detonation of explosive device on or near target; delivery via person, vehicle, or	Instantaneous; Additional "secondary devices" may be used, lengthening	Extent of damage is determined by type and quantity of explosive.	Effects generally static other than cascading consequences, incremental

Methods of Implementation for Terrorism				
Description	**Application Mode**	**Duration**	**Extent of Effects**	**Mitigating or Exacerbating Conditions**
	projectile.	the time duration of the hazard until the attack site is determined to be clear.		structural failure, etc.
Chemical Agent	Liquid/aerosol contaminants can be dispersed using sprayers or other aerosol generators; liquids vaporizing from puddles / containers; or munitions.	Chemical agents may pose viable threats for hours to weeks depending on the agent and the conditions in which it exists.	Contamination can be carried out of the initial target area by persons, vehicles, water and wind. Chemicals may be corrosive or otherwise damaging over time if not remediated.	Weather conditions and availability of shielding can greatly impact effectiveness of chemical agents.
Arson/ Incendiary Attack	Initiation of fire or explosion on or near target via direct contact or remotely via projectile.	Generally minutes to hours.	Extent of damage is determined by type and quantity of device / accelerant and materials present at or near target.	Effects generally static other than cascading consequences, Incremental structural failure, etc.
Armed Attack	Tactical assault or sniping from remote location.	Generally minutes to days.	Varies based upon the perpetrators' intent and capabilities.	Inadequate security can allow easy access to target, easy concealment of weapons and undetected initiation of an attack.
Biological Agent	Liquid or solid contaminants can be dispersed using sprayers / aerosol generators or by point or line sources such as munitions, covert deposits and moving sprayers.	Biological agents may pose viable threats for hours to years depending on the agent and the conditions in which it exists.	Depending on the agent used and the effectiveness with which it is deployed, contamination can be spread via wind and water. Infection can be spread via human or animal vectors.	Weather conditions can greatly impact effectiveness of biological agents.
Cyberterrorism	Electronic attack using one computer system against another.	Minutes to days.	Generally no direct effects on built environment.	Inadequate security can facilitate access to critical computer systems, allowing them to be used to conduct attacks.
Agriterrorism	Direct, generally Covert	Days to months.	Varies by type of incident. Food	Inadequate security can facilitate

Methods of Implementation for Terrorism				
Description	**Application Mode**	**Duration**	**Extent of Effects**	**Mitigating or Exacerbating Conditions**
	contamination of food supplies or introduction of pests and / or disease agents to crops and livestock.		contamination events may be limited to discrete distribution sites, whereas pests and diseases may spread widely. Generally no effects on built environment.	adulteration of food and introduction of pests and disease agents to crops and livestock.
Radiological Agent	Radioactive contaminants can be dispersed using sprayers / aerosol generators, or by point or line sources such as munitions, covert deposits and moving sprayers.	Contaminants may remain hazardous for seconds to years depending on material used.	Initial effects will be localized to site of attack; depending on meteorological conditions, subsequent behavior of radioactive contaminants may be dynamic.	Duration of exposure, distance from source of radiation, and the amount of shielding between source and target determine exposure to radiation.

Location of the Terrorism Hazard

Terrorism, bring a man made hazard, is not tied to specific geography or topography, but rather is usually tied to specific features of a community. These features are usually of high value to the community, or are necessary for the community's operations or livelihood. Several such locations exist in the City of Galveston, including:

- Petrochemical terminals
- Ferry
- I-45 Causeway
- The Galveston National Lab / UTMB
- The Port of Galveston
- Water pipelines and treatment facilities
- Cruise ship terminals

In addition to the above fixed facilities, Galveston – as a barrier island – is host to thousands of seasonal residents and tourists, particularly during the summer months. In addition, Galveston hosts several annual events that draw large crowds to public spaces, including:

- Mardi Gras
- The Lone Star Bike Rally
- Dickens on the Strand

Terrorists most often search for highly visible targets which they can strike while avoiding detection.
However, the motivation behind terrorist events can be varied and the entire planning area is considered at risk.

Severity of the Terrorism Hazard

As terrorism is a man made hazard, the severity of the hazard within the City is impossible to predict. Scenarios range from minor disruptions to catastrophic damages and fatalities. There is no scale for measure the severity of an act of terrorism, and a great deal of variability between events. Terrorism can be targeted at specific individuals or the campus as a whole. They may be premeditated or occur as the result of an opportunity.

The US Department of Homeland Security monitors the terrorism threat on a national level, and is responsible for maintaining the Homeland Security Advisory System. This system was established by Presidential Directive, and is designed to guide protective measures when specific information to a particular sector or geographic region is received. It combines threat information with vulnerability assessments and provides communications to public safety officials and the public.

Figure 6.3.12-1 illustrates the Homeland Security Advisory System.

Figure 6.3.12-1
Homeland Security Advisory System
(Source: US Department of Homeland Security)

Impact on Life and Property from the Terrorism Hazard

Depending on the method chosen, the impact of a terrorist act on life and property in Galveston could be devastating. People, property and infrastructure are all potentially at risk to devastating impacts. The economic impacts to the City could be catastrophic, depending on the severity of the attack and the property and infrastructure that is damaged or destroyed.

Occurrences of the Terrorism Hazard

There are no documented instances of terrorism in the City of Galveston to date. However, the City, and its partner UTMB, are home to many potential high-value targets and events, as described earlier in this section.

Probability of Future Occurrences of the Terrorism Hazard

Occurrences of the terrorism incident hazard are solely dependent on external factors. An incident must involve human action, which cannot be predicted with any degree of certainty.

Given the lack of documented historical occurrences specific to Galveston, it's impossible to predict the statistical probability of future occurrences of the terrorism hazard, as there's not enough data from which conclusions can be drawn. Therefore, the probability of future occurrence can be rated as Low.

6.3.13 Tsunami

Description of the Tsunami Hazard

A tsunami is a series of water waves (called a tsunami wave train) caused by the displacement of a large volume of a body of water, such as an ocean or a large lake. Due to the immense volumes of water and energy involved, tsunamis can devastate coastal regions. Casualties can be high because the waves move faster than humans can run.

Earthquakes, volcanic eruptions and other underwater explosions (detonations of nuclear devices at sea), landslides and other mass movements, bolide impacts, and other disturbances above or below water all have the potential to generate a tsunami. From the area of the disturbance, tsunami waves travel outwards in all directions. They can cause damage to coastal areas hundreds or thousands of miles from their point of origin.

Some meteorological conditions, such as deep depressions that cause tropical cyclones, can generate a storm surge, called a meteotsunami, which can raise tides several feet above normal levels. The displacement comes from low atmospheric pressure within the centre of the depression. As these storm surges reach shore, they may resemble (though are not) tsunamis, inundating vast areas of land. Such a storm surge inundated Myanmar in May 2008.

In the open ocean, tsunami waves travel at speeds of up to 600 MPH. They are not visible to humans, however, as they are hidden by the deep water that they travel in. The time lapse between wave crests typically ranges from 5 to 90 minutes. As the tsunami wave approaches shallow coastal waters, the wave slows down. The wave height becomes noticeable once it moves into shallower waters. Waves can, without warning, rise to several feet – in some cases, tens of feet. Although the waves do slow down when they encounter shallow waters, this reduction in speed is negligible, considering that a 100 foot wave has been traveling at up to 600 MPH across the open ocean. A tsunami can throw a series of waves more than 100’ in height into the shore. The waves typically occur in sets, and the first wave is almost never the largest. Successive waves may continue to arrive for many hours after the initial arrival.

Location of the Tsunami Hazard

Coastal areas at greatest risk from tsunamis are those less than 50’ above mean sea level, and those within 1 mile of the shore. As the City of Galveston is far below 50’ MSL, the entire City is within the potential hazard area.

Severity of the Tsunami Hazard

The severity of a tsunami can be measured using the Papadopoulos/Imamura Tsunami Scale. This 12-point scale of tsunami intensity was proposed in 2001 by Gerassimos Papadopoulos and Fumihiko Imamura. The tsunami scale is arranged according to a tsunami's effects on humans (a), effects on objects including boats (b), and damage to buildings (c). The scale is presented in Table 6.3.13-1.

Note that 1 meter is 3.28 feet.

Table 6.3.13-1
Papdopoulos/Imamura Tsunami Intensity Scale
(Source: http://geology.about.com/library/bl/bltsunamiscalenew.htm)

Papadopoulos/Imamura Tsunami Scale

Level	Damage	Wave Height (in meters)	Description
I	Not felt		
II	Scarcely felt		a. Felt by few people onboard small vessels. Not observed on the coast.
III	Weak		a. Felt by most people onboard small vessels. Observed by a few people on the coast.
IV	Largely Observed		a. Felt by all onboard small vessels and by few people onboard large vessels. Observed by most people on the coast.
			b. Few small vessels move slightly onshore.
V	Strong	1 meter	a. Felt by all onboard large vessels and observed by all on the coast. Few people are frightened and run to higher ground.
			b. Many small vessels move strongly onshore, few of them crash into each other or overturn. Traces of sand layer are left behind on ground with favorable circumstances. Limited flooding of cultivated land.
			c. Limited flooding of outdoor facilities (such as gardens) of near-shore structures.
VI	Slightly damaging	2 meters	a. Many people are frightened and run to higher ground.
			b. Most small vessels move violently onshore, crash strongly into each other, or overturn.
			c. Damage and flooding in a few wooden structures. Most masonry buildings withstand.
VII	Damaging	3 meters	a. Many people are frightened and try to run to higher ground.
			b. Many small vessels damaged. Few large vessels oscillate violently. Objects of variable size and stability overturn and drift. Sand layer and accumulations of pebbles are left behind. Few aquaculture rafts washed away.
			c. Many wooden structures damaged, few are demolished or washed away. Damage of grade 1 and flooding in a few masonry buildings.
VIII	Heavily damaging	4 meters	a. All people escape to higher ground, a few are washed away.
			b. Most of the small vessels are damaged, many are washed away. Few large vessels are moved ashore or crash into each other. Big objects are drifted away. Erosion and littering of the beach. Extensive flooding. Slight damage in tsunami-control forests and stop drifts. Many aquaculture rafts washed away, few partially damaged.
			c. Most wooden structures are washed away or demolished. Damage of grade 2 in a few masonry buildings. Most reinforced-concrete buildings sustain damage, in a few damage of grade 1 and flooding is observed.
IX	Destructive	8 meters	a. Many people are washed away.
			b. Most small vessels are destroyed or washed away. Many large vessels are moved violently ashore, few are destroyed. Extensive erosion and littering of the beach. Local ground subsidence. Partial destruction in tsunami-control forests and stop drifts. Most aquaculture rafts washed away, many

Papadopoulos/Imamura Tsunami Scale			
Level	**Damage**	**Wave Height (in meters)**	**Description**
			partially damaged.
			c. Damage of grade 3 in many masonry buildings, few reinforced-concrete buildings suffer from damage grade 2.
X	Very destructive	12 meters	a. General panic. Most people are washed away.
			b. Most large vessels are moved violently ashore, many are destroyed or collide with buildings. Small boulders from the sea bottom are moved inland. Cars overturned and drifted. Oil spills, fires start. Extensive ground subsidence.
			c. Damage of grade 4 in many masonry buildings, few reinforced-concrete buildings suffer from damage grade 3. Artificial embankments collapse, port breakwaters damaged.
XI	Devastating	16 meters	b. Lifelines interrupted. Extensive fires. Water backwash drifts cars and other objects into the sea. Big boulders from sea bottom are moved inland.
			c. Damage of grade 5 in many masonry buildings. Few reinforced-concrete buildings suffer from damage grade 4, many suffer from damage grade 3.
XII	Completely devastating	32 meters	c. Practically all masonry buildings demolished. Most reinforced-concrete buildings suffer from at least damage grade 3.

Any tsunami could be devastating to the City of Galveston. With low elevation and limited means of evacuation, the impact to the City could be catastrophic, were the seawall to fail to protect the City.

Impact on Life and Property from the Tsunami Hazard

Tsunamis can cause great property damage and loss of life where they come ashore, with most fatalities resulting from drowning. Associated risks include water pollution, saltwater inundation, damaged infrastructure, and extensive flooding.

Occurrences of the Tsunami Hazard

Major tsunamis occur about once per decade. Based on historical data, about 59% of the world's tsunamis have occurred in the Pacific Ocean, 25% in the Mediterranean Sea, 12% in the Atlantic Ocean, and 4% in the Indian Ocean. The Mediterranean and Caribbean Seas both have small subduction zones, and have histories of locally destructive tsunamis. Only a few tsunamis have been generated in the Atlantic and Indian Oceans. In the Atlantic Ocean, there are no subduction zones at the edges of plate boundaries to spawn such waves except small subduction zones under the Caribbean and Scotia arcs.

The most destructive tsunami to impact the US struck Hilo, Hawaii in 1960. The magnitude-9.5 Great Chilean Earthquake of May 22, 1960 is the strongest earthquake ever recorded. Its epicenter, off the coast of South Central Chile, generated one of the most destructive tsunami of the 20th Century. It also caused a volcanic eruption.

It spread across the entire Pacific Ocean, with waves measuring up to 75' high. The first tsunami arrived at Hilo approximately 15 hours after it originated off the coast of South Central Chile. The highest wave at Hilo Bay was measured at around 35 ft. 61 lives were lost allegedly due to people's failure to heed warning sirens.

Almost 22 hours after the quake, the waves hit the ill-fated Sanriku coast of Japan, reaching up to 9' above high tide, and killed 142 people. Up to 6,000 people died in total worldwide due to the earthquake and tsunami

In the modern era, the best known occurrence of the tsunami hazard was the Indonesian Tsunami that occurred December 26, 2004. The 2004 Indian Ocean earthquake was an undersea megathrust earthquake that occurred on December 26, 2004, with an epicenter off the west coast of Sumatra, Indonesia. The earthquake was caused by subduction and triggered a series of devastating tsunamis along the coasts of most landmasses bordering the Indian Ocean, killing nearly 230,000 people in 14 countries, and inundating coastal communities with waves up to 100' high. It was one of the deadliest natural disasters in recorded history. Indonesia was the hardest hit, followed by Sri Lanka, India, and Thailand.

With a magnitude of between 9.1 and 9.3, it is the second largest earthquake ever recorded on a seismograph. This earthquake had the longest duration of faulting ever observed, between 8.3 and 10 minutes. It caused the entire planet to vibrate as much as 0.4 inches and triggered other earthquakes as far away as Alaska.

There has been 1 confirmed occurrence of a tsunami affecting Galveston. The origin point for this event was a major earthquake that struck the island of Puerto Rico October 11, 1918. The magnitude for the earthquake has been reported at around 7.5 (or Level IX in the Rossi-Forel scale used at that time); however, that might not be an exact number. The earthquake triggered a tsunami with waves measured at approximately 20' that lashed the west coast of Puerto Rico and is remembered as one of the worst natural disasters that have struck the island. The losses resulting from the disaster were approximately 116 casualties and $4 million in property. The tsunami reached Galveston as a disturbance on tide gauges. No damage or wave height information was recorded from this event.

Probability of Future Occurrences of the Tsunami Hazard

In August 2008, a qualitative tsunami hazard assessment was prepared by NOAA and the US Geological Service (USGS). This assessment indicated that the US Gulf Coast has a very low risk of tsunamis. This assessment was based on National Geophysical Data Center (NGDC) and USGS data. The report specifically stated that the vulnerability was low based on the following factors:

- Very low wave runup
- Very low hazard frequency
- Very low earthquake occurrence
- No reported fatalities.

Based on the information in this assessment, and in consideration of the almost non-existent historical occurrences, the probability of a future occurrence of the tsunami hazard is rated as Low.

6.3.14 Wildfire / Urban Fire

Description of the Wildfire / Urban Fire Hazard

Fire is the rapid oxidation of a material in the chemical process of combustion, releasing heat, light, and various reaction products. Slower oxidative processes like rusting or digestion are not included by this definition. The flame is the visible portion of the fire and consists of glowing hot gases. If hot enough, the gases may become ionized to produce plasma. Depending on the substances alight, and any impurities outside, the color of the flame and the fire's intensity might vary.

Fire in its most common form can result in conflagration, which has the potential to cause physical damage through burning. Fire is an important process that affects ecological systems across the globe. The positive effects of fire include stimulating growth and maintaining various ecological systems. Fire has been used by humans for cooking, generating heat, signaling, and propulsion purposes. The negative effects of fire include decreased water purity, increased soil erosion, an increase in atmospheric pollutants and an increased hazard to human life.

Wildfires, also known as a wild land fire, are any fire that occurs on grassland, forest or prairie, regardless of ignition source, damages or benefits. Wildfires are usually a naturally-occurring phenomenon, though they can be caused by human action – namely arson. A wildfire differs from other fires by its extensive size, the speed at which it can spread out from its original source, its potential to change direction unexpectedly, and its ability to jump gaps such as roads, rivers and fire breaks. Wildfires are characterized in terms of the cause of ignition, their physical properties such as speed of propagation, the combustible material present, and the effect of weather on the fire.

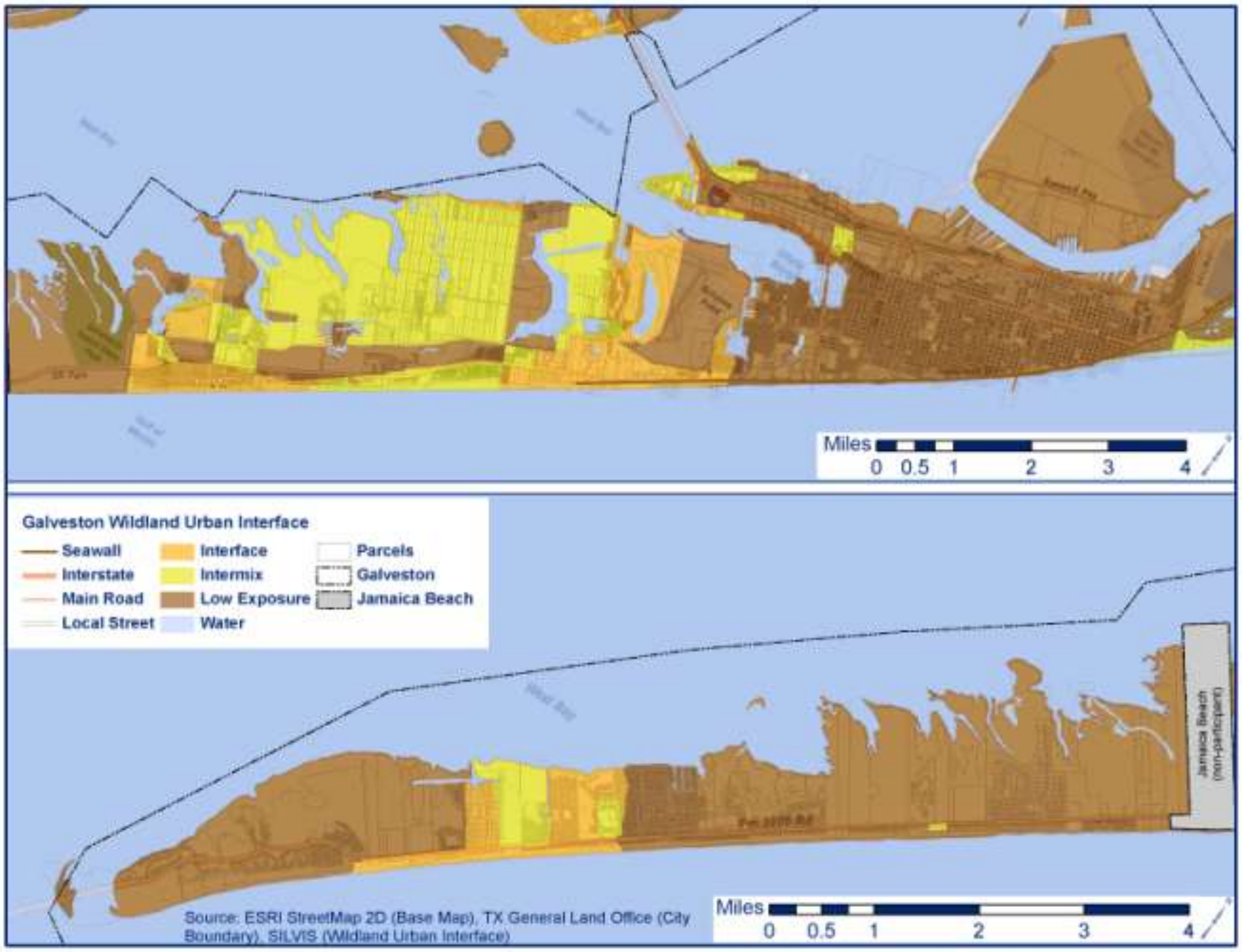
Urban fires are considered a man-made hazard, in that their origins can arise from human activity and be fueled by dense development. (For the purposes of this hazard profile, urban fires are assumed to be accidental and their consequences unintended.)

The *National Fire Plan,* issued by the US Departments of Agriculture and Interior, defines the urban/wild land interface as "…the line, area, or zone where structures and other human development meet or intermingle with undeveloped wild land or vegetative fuels."

Location of the Wildfire / Urban Fire Hazard

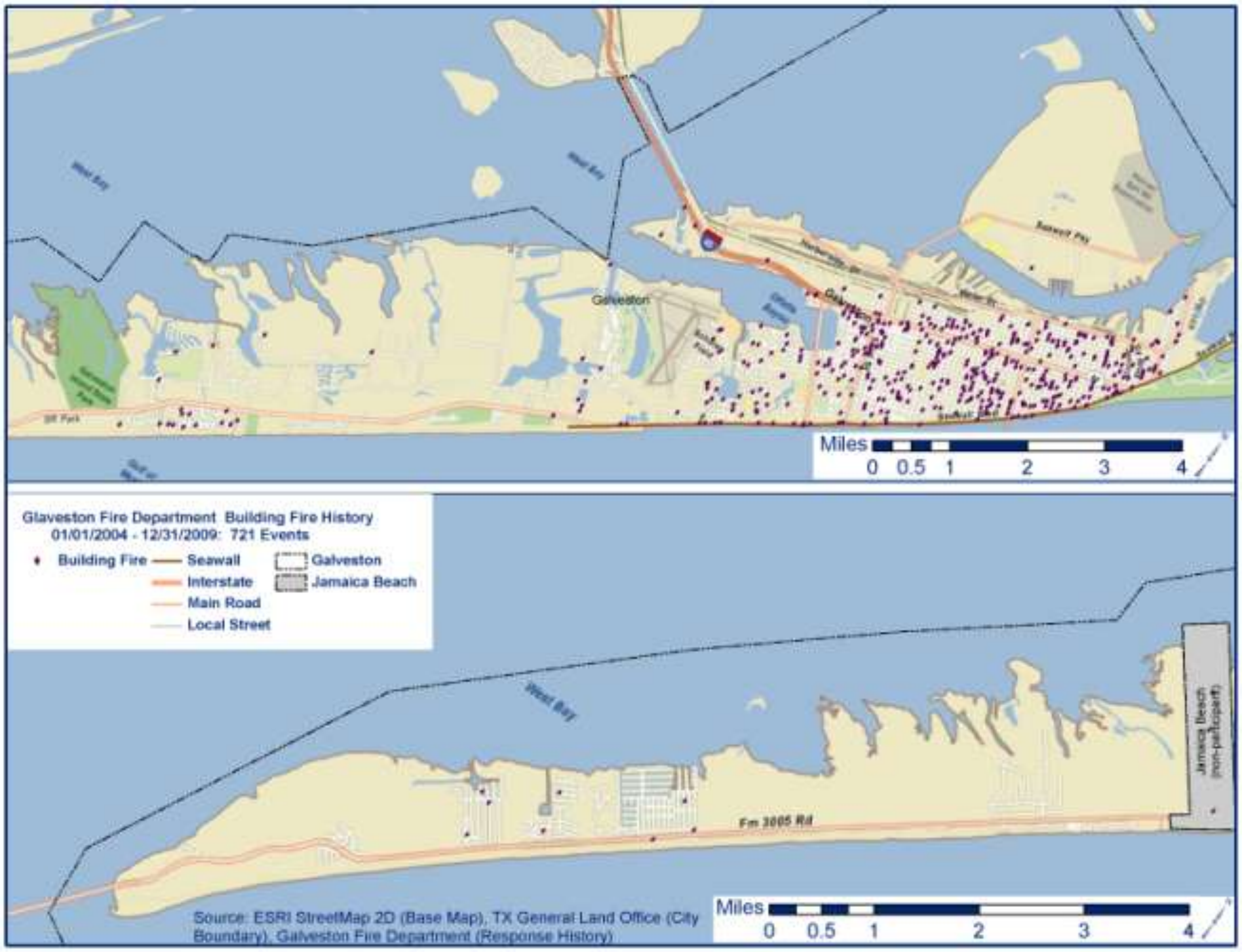
By definition, wildfires are located in less populated areas. Urban fires are located in urban areas. The City of Galveston is home to both areas. Map 6.3.14-1 illustrates the most probable locations for wildland fires.

Map 6.3.14-1
Wildland Urban Interface
(Source: ESRI, GLO, SILVIS)



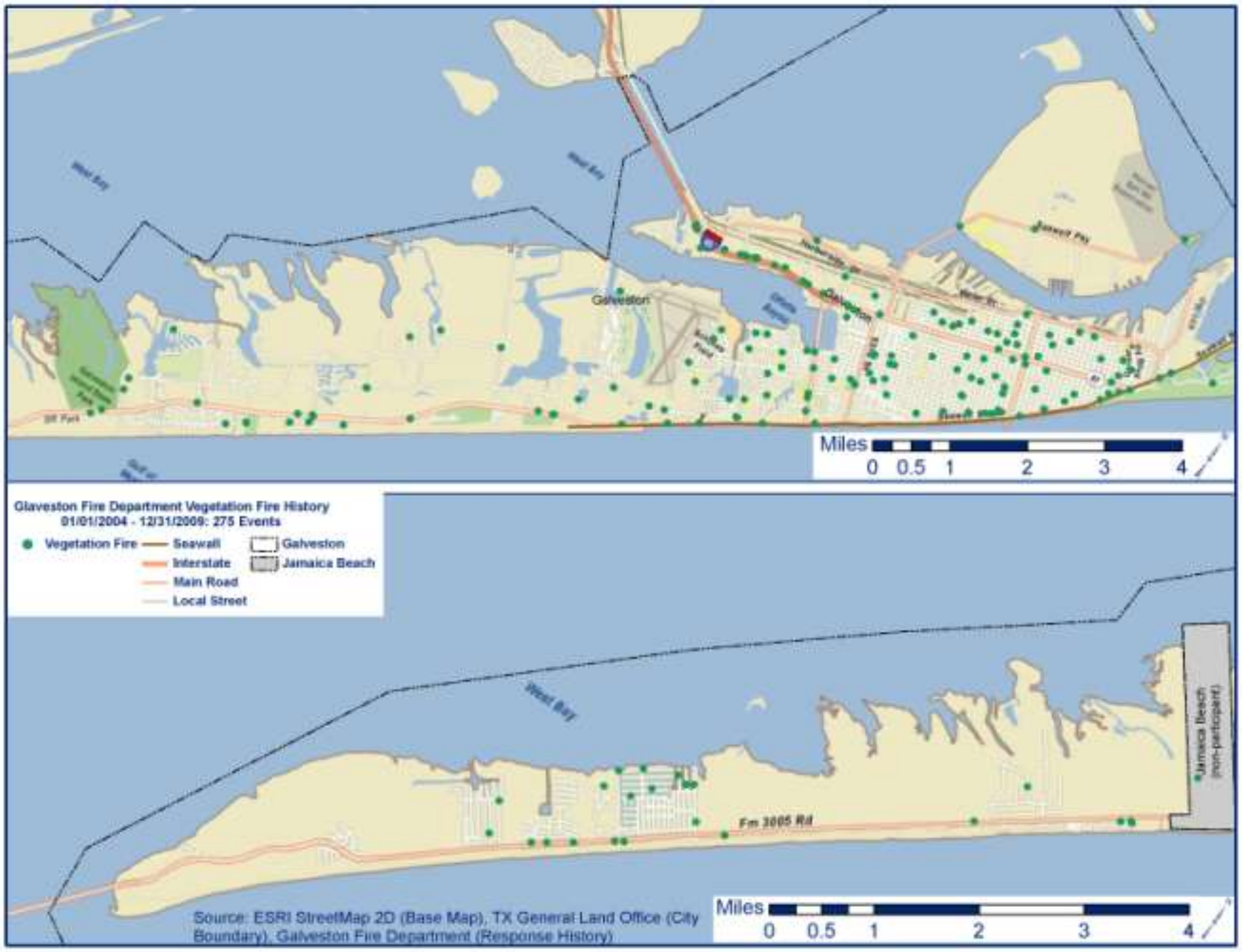
Map 6.3.14-2 depicts the locations of building fires in the City of Galveston between January 2004 and December 2009. A total of 721 incidents were reported by the Galveston Fire Department.

Map 6.3.14-2
Structure Fire Locations in Galveston, 2004-2009
(Source: ESRI, GLO, Galveston Fire Department)



Map 6.3.14-3 depicts the locations of vegetation, brush and wild fires in the City of Galveston between January 2004 and December 2009. A total of 275 incidents were reported by the Galveston Fire Department.

Map 6.3.14-3
Vegetative, Brush and Wildland Fire Locations in Galveston, 2004-2009
(Source: ESRI, GLO, Galveston Fire Department)



Severity of the Wildfire / Urban Fire Hazard

According to the *National Fire Plan* (2000), the wild land fire risk is considered the "most significant fire service problem of the Century."

Fire Danger is a description of the combination of both constant and variable factors that affect the initiation, spread, and difficulty to control a wildfire on an area. Since 1974, the National Park Service has used five Adjective Fire Danger ratings to describe danger levels in public information releases and fire prevention signing. Table 6.3.14-1 describes these ratings.

Table 6.3.14-1
Fire Danger Rating System
(Source: National Park Service - http://www.nps.gov/fire/public/pub_und_understandingfire.cfm)

Fire Danger Rating System		
Rating	**Basic Description**	**Detailed Description**
CLASS 1: Low Danger (L) COLOR CODE: **Green**	Fires not easily started	Fuels do not ignite readily from small firebrands. Fires in open or cured grassland may burn freely a few hours after rain, but wood fires spread slowly by creeping or smoldering and burn in irregular fingers. There is little danger of spotting.
CLASS 2: Moderate Danger (M) COLOR CODE: **Blue**	Fires start easily and spread at a moderate rate	Fires can start from most accidental causes. Fires in open cured grassland will burn briskly and spread rapidly on windy days. Woods fires spread slowly to moderately fast. The average fire is of moderate intensity, although heavy concentrations of fuel – especially draped fuel -- may burn hot. Short-distance spotting may occur, but is not persistent. Fires are not likely to become serious and control is relatively easy.
CLASS 3: High Danger (H) COLOR CODE: **Yellow**	Fires start easily and spread at a rapid rate	All fine dead fuels ignite readily and fires start easily from most causes. Unattended brush and campfires are likely to escape. Fires spread rapidly and short-distance spotting is common. High intensity burning may develop on slopes or in concentrations of fine fuel. Fires may become serious and their control difficult, unless they are hit hard and fast while small.
CLASS 4: Very High Danger (VH) COLOR CODE: **Orange**	Fires start very easily and spread at a very fast rate	Fires start easily from all causes and immediately after ignition, spread rapidly and increase quickly in intensity. Spot fires are a constant danger. Fires burning in light fuels may quickly develop high-intensity characteristics - such as long-distance spotting - and fire whirlwinds, when they burn into heavier fuels. Direct attack at the head of such fires is rarely possible after they have been burning more than a few minutes.
CLASS 5: Extreme (E) COLOR CODE: **Red**	Fire situation is explosive and can result in extensive property damage	Fires under extreme conditions start quickly, spread furiously and burn intensely. All fires are potentially serious. Development into high-intensity burning will usually be faster and occur from smaller fires than in the Very High Danger class (4). Direct attack is rarely possible and may be dangerous, except immediately after ignition. Fires that develop headway in heavy slash or in conifer stands may be unmanageable while the extreme burning condition lasts. Under these conditions, the only effective and safe control action is on the flanks, until the weather changes or the fuel supply lessens.

Galveston could expect to fall within the entire range of the Fire Danger Rating System.

Impact on Life and Property from the Wildfire / Urban Fire Hazard

The interface problem has escalated over the last twenty years, primarily due to increases in population, urban expansion, land-management decisions, and the desire of humans to intermingle with nature. The relationship between humans, their property and wild land areas has significantly increased human exposure to wild fires, and has increased the potential for wildfires to spread to urban areas.

More and more people are choosing to live in woodland settings or near forests or rural areas. Many of these homes are nestled in classic fire-interface hazard zones, such as ridgelines or cliff edges. This placement increases the property's exposure to wild land fire interface incidents. Years of fire suppression practices have significantly disturbed natural fire occurrences. Nature uses wildfire as a renewal process, and suppression practices can interrupt this cycle. The result has been a gradual but steady accumulation of understory and canopy fuels. These fuels can feed high-energy, intense wildfires and further increase the hazards from and exposure to wild land interface problems.

In 2007, the Texas Fire Incident Reporting System (TEXFIRS) reported that 138 civilian Texans lost their lives to fire, and another 683 were injured. The majority of these fires involved residential structures, with the kitchen or cooking area identified as the most common point of origin. More than $450 million in property damage occurred because of these fires.

Occurrences of the Wildfire / Urban Fire Hazard

Texas has seen a dramatic increase in the number of wildfires in the previous three decades. From January 2005 through September 2006, the Texas Forest Service (TFS) responded to 4,370 wildfires that burned approximately 1.6 million acres.

In 2007, 1,033 Texas fire departments reported more than 1.4 million incidents to the Texas Fire Incident Reporting System (TEXFIRS). 73,704 of these incidents were fires, which equates to a fire occurring every 7 minutes somewhere in Texas.

The City of Galveston was the site of one of the worst urban fires in Texas history. In November 1885, a fire began at a foundry at 17th Street and Strand Avenue, in Galveston's Central Business District. A stiff wind was blowing from the northeast, which carried sparks from the fire several blocks. Within minutes, the fire had spread several blocks, to 19th Street and Avenue O.

Galveston's first professional fire department was barely a month old when the fire broke out, and was no match for the conflagration. The pressure on its newly installed saltwater system proved insufficient, and bits of shell clogged the nozzles of the fire hose. By the time it burned itself out, the fire had consumed forty-two blocks, and destroyed 568 buildings and homes. More than $1 MM in damage ($23 MM in 2009 dollars) was sustained. Despite this incredible level of damage, no fatalities occurred as a result of the blaze.

As a result of the Great Galveston Fire of 1885, as the event came to be known, building standards within the City were changed to require the use of fire resistant materials within the Central Business District.

Probability of Future Occurrences of the Wildfire / Urban Fire Hazard

The probability of wildfire frequently changes, based on fuel loads and weather conditions. The probability of urban fire is harder to predict, as it often involves human behavior. Consideration of the probability of urban fire, however, must take into consideration the number of abandoned / vacant structures on the island (as a result of Hurricane Ike), and the number of historic, wood-frame structures found throughout the Island's East End. Based on current conditions and historic occurrence, the probability of a future occurrence is High.

6.4 Methodology for Identifying Hazards of Concern

In accordance with the requirements of the Interim Final Rule all hazards with potential to affect the City of Galveston are profiled in this section of the Plan. However, because this is a City-level hazard mitigation plan it is useful to identify the hazards that are of the most concern City-wide, so these can be the focus of more detailed assessment.

Various national, regional and local sources were used to identify and classify different hazards for the City of Galveston. The criteria used were:

1. **History** – incorporating historical accounts and records that the hazard has affected the City often in the past, and that the hazard has occurred often and/or with widespread or severe consequences.
2. **Potential for mitigation** – acknowledging that there are ways to address the hazard, and that the methods are technically feasible and have the potential to be cost-effective [i.e. mitigation measures are available at a reasonable cost, and damages to property, lives and/or community functions would be reduced or eliminated.]
3. **Presence of susceptible areas or vulnerability** – indicating that the City has numerous facilities, operations or populations that may be subjected to damage from the hazard.
4. **Data availability** – demonstrating that sufficient quality data is available to permit an accurate and comprehensive risk assessment.
5. **Federal disaster declarations and local emergency declarations** – noting that the City has received numerous disaster declarations for the particular hazard.

The table on the following pages lists the hazards, describes the rationale for identifying (or not identifying) hazards as significant, shows sources of information that were consulted for the determination, and the disposition of the hazard with regard to hazard identification and quantitative risk assessment in this plan. The hazards in the shaded portion of the table are those that were identified by the City of Galveston's HMPSC as significant enough to warrant a quantitative risk assessment.

In order to determine the probability of future occurrences of each hazard profiled, the following scale was developed:

Low indicates that the hazard has not yet occurred, or has occurred infrequently, and has resulted or is anticipated to result in contained or minimal damage.
Moderate indicates that the hazard has occurred or is occurring with some regularity, but with limited spatial impacts, and either has or is anticipated to result in moderate or limited damage
High indicates that the hazard regularly occurs with some frequency, and has the potential to impact a widespread area of the jurisdiction

Specific information related to the qualitative and quantitative assessment determinations for the profiled hazards can be found in Section 7, Risk Assessment.

Table 6.4-1
City of Galveston Qualitative Hazard Ranking

Qualitative Hazard Ranking			
Hazard	**Rationale**	**Sources**	**Disposition**
Aircraft Incident	Low probability based on historical data, but impacts potentially significant in site specific areas.	FEMA, Galveston Fire Department, Historical accounts	Not profiled due to low probability and mitigation potential
Biological event	Low annual probability, widespread impacts, but losses generally limited except in most extreme events	FEMA, Centers for Disease Control and Prevention (CDC), Galveston County Health Department	Profiled, but not part of quantitative Risk Assessment
Coastal Erosion	Low to moderate probability and risks, due to City's status as a barrier island	FEMA, NOAA, US Geologic Service (USGS), GLO, City of Galveston, Texas State Hazard Mitigation Plan	Profile and Quantitative Risk Assessment completed
Coastal Retreat	Low to moderate probability and risks due to City's status as a barrier island	FEMA, NOAA, US Geologic Service (USGS), GLO, City of Galveston, Texas State Hazard Mitigation Plan	Profiled, but not part of quantitative Risk Assessment
Coastal Subsidence (includes land subsidence)	Low probability and risks due to City's status as a barrier island	FEMA, NOAA, US Geologic Service (USGS), GLO, City of Galveston, Texas State Hazard Mitigation Plan	Profiled, but not part of quantitative Risk Assessment
Dam/Levee Failure (Flooding)	Low annual probability of occurrence with limited consequences	FEMA, US Army Corps of Engineers (USACE), USGS, Galveston County, Texas State Hazard Mitigation Plan	Not profiled due to low probability of occurrence
Drought	Low annual probability and risks, with impacts relatively limited	FEMA, US Department of Agriculture (USDA), Galveston County, Texas State Hazard Mitigation Plan	Profiled, but not part of quantitative Risk Assessment
Earthquake	Low probability based on historical data and relationship to known faults	FEMA, USGS, Texas State Hazard Mitigation Plan	Not profiled due to low probability of occurrence

Qualitative Hazard Ranking			
Hazard	**Rationale**	**Sources**	**Disposition**
Environmental Disaster	Low to moderate impacts to buildings and infrastructure, potentially high impacts to people	FEMA, USDA, EPA, TCEQ, City	Profiled, but not part of quantitative Risk Assessment
Expansive Soils	Low probability based on historical data, but impacts potentially significant in site specific areas	FEMA, USGS, Texas State Hazard Mitigation Plan	Not profiled due to low probability of occurrence
Extreme Heat	Moderate annual probability, widespread impacts, but losses generally limited except in most extreme events.	FEMA, NCDC, Texas State Hazard Mitigation Plan	Not profiled due to low mitigation potential
Extreme Wind (includes hurricane wind, straight line wind and tornado)	High probability of occurrences, with significant risks to people, buildings and infrastructure	FEMA, NCDC, HAZUS, City, Texas State Hazard Mitigation Plan	Profile and Quantitative Risk Assessment completed
Flood (includes storm surge)	High annual probability, widespread impacts, with moderate impacts to people and high impacts to buildings and infrastructure	FEMA Flood Insurance Studies, FEMA Flood Insurance Rate Maps, FEMA Public Assistance records, FEMA National Flood Insurance Program claims data, USACE, and NOAA, studies and records, Texas State Hazard Mitigation Plan	Profile and Qualitative Risk Assessment completed
Hail	Low probability of occurrences, but losses are typically limited	FEMA, NCDC, Texas State Hazard Mitigation Plan	Not profiled due to low mitigation potential
Hazardous Material Incident (Fixed Site and Transport)	Low to moderate annual probability, but potential for significant consequences in site specific areas	US Environmental Protection Agency, FEMA HAZUS (Hazards US) software, Galveston Fire Department, UTMB	Profile and Quantitative Risk Assessment completed
Hurricane			Profiled as Extreme Wind and Flood
Land Subsidence	Low probability based on historical data, but impacts potentially significant in site specific areas	FEMA, USGS, Texas State Hazard Mitigation Plan	Profiled as Coastal Subsidence

Qualitative Hazard Ranking			
Hazard	**Rationale**	**Sources**	**Disposition**
Landslide	Low probability based on historical data, impacts limited based on local elevation	FEMA, USGS, FEMA Flood Insurance Study	Not profiled due to low probability of occurrence
Lightning	High annual probability, but low impacts to people, buildings and infrastructure	NOAA, NWS, FEMA	Profiled, but not part of quantitative Risk Assessment
Mosquito-Borne Disease / Communicable Disease / Pandemic			Profiled as Biological Event
Sea Level Rise	Low to moderate impacts expected to people, buildings and infrastructure	GLO, NOAA, USGS	Profiled, but not part of quantitative Risk Assessment
Severe Winter Storm	Low historic rate of occurrences, with low impacts and losses	FEMA, NCDC, Texas State Hazard Mitigation Plan	Not profiled due to low probability of occurrence
Terrorism	Moderate annual probability, widespread impacts, with moderate to high impacts expected to people, buildings and infrastructure in vicinity of incident, depending on type of incident	Local law enforcement, City Emergency Management, FEMA	Profiled, but not part of qualitative Risk Assessment
Thunderstorm			Profiled as Lightning, Flood and Extreme Wind, respectively
Tornado			Profiled as Extreme Wind
Tsunami	Low probability based on historical data, but impacts potentially significant in site specific areas	FEMA, NHC, NCDC	Profiled, but not part of qualitative Risk Assessment
Wildfire / Urban Fire	High probability based on historical data, with impacts potentially significant in site specific areas	FEMA, Galveston Fire Department, Texas Forest Service, Texas State Hazard Mitigation Plan	Profile and Qualitative Risk Assessment completed

Qualitative Hazard Ranking			
Hazard	**Rationale**	**Sources**	**Disposition**
Volcano	Low probability based on historical data	FEMA, USGS	Not profiled due to low probability of occurrence

Note: The data in this table is intended only to give a general sense of the significance of hazards in the City, relative to each other. See Appendix M for a complete listing of all hazards and descriptions.

Summary

Based on local knowledge, discussion and the qualitative ranking above, the HMPSC recommended including 4 natural hazards and 1 technological / manmade hazard in the more detailed quantitative risk assessment in Section 7:

- Coastal Erosion
- Extreme Wind
- Flood
- Hazardous Materials Incident (Fixed Site and Transport)
- Wildfire / Urban Fire

Note on Consistency with the 2008 State of Texas Hazard Mitigation Plan

As part of the process of developing the City of Galveston Hazard Mitigation Plan, the HMPSC carefully reviewed the 2008 State of Texas Hazard Mitigation Plan (SHMP), with the goal of ensuring consistency between the two documents, primarily in the areas of hazard identification, risk assessment and mitigation strategy. The SHMP comprises a different list of hazards but the most significant hazards statewide are part of both documents, and are generally prioritized in the same way.

Summary Description of the City's Vulnerability to Hazards

The DMA 2000 legislation and related FEMA planning guidance require mitigation plans to include discussion of community vulnerability to natural hazards. Vulnerability is generally defined as the damage (including direct damages and loss of function) that would occur when various levels of hazards impact a structure, operation or population. For example vulnerability can be expressed as the percent damage to a building when it is flooded, or the number of days that a government office will be shut down after a wind storm, etc., assuming there is sufficient detailed data available to support the calculations.

As illustrated in Section 6 (Hazard Identification), the City is subject to numerous natural and manmade hazards, although in some cases the hazards have rarely impacted the area, or their effects have been relatively minor. The most frequent hazard that impact the City are typically flood and extreme wind. However, it is important to recognize that several other hazards present significant risks (i.e. potential for future losses) to the City, even though they have occurred infrequently in the past, or have not caused much damage.

Wildfire and Urban Fire are of particular concern to the City, as is Hazardous Materials Incidents. For all practical purposes, the City is reliant upon local resources to respond to and manage these types of events. As the City is still working towards recovering from the devastation of Hurricane Ike, and will be for years to come, their resources are somewhat limited. They are still working with FEMA to replace equipment and facilities that were damaged when Ike made landfall, and this process is expected to go on well into the future. The Municipal Utilities Department and the Fire Department in particular were devastated by losses as a result of Hurricane Ike. These losses have negatively impacted the City's ability to respond to and manage certain hazard events. This has made the City more determined to pursue effective mitigation actions and projects, to offset these limitations wherever possible.

Other hazards, though unlikely, could also cause catastrophic damage in the City. In particular, the City could be seriously damaged by a hazardous material incident, if it occurred in a heavily populated or area or caused damage to the I-45 Causeway.